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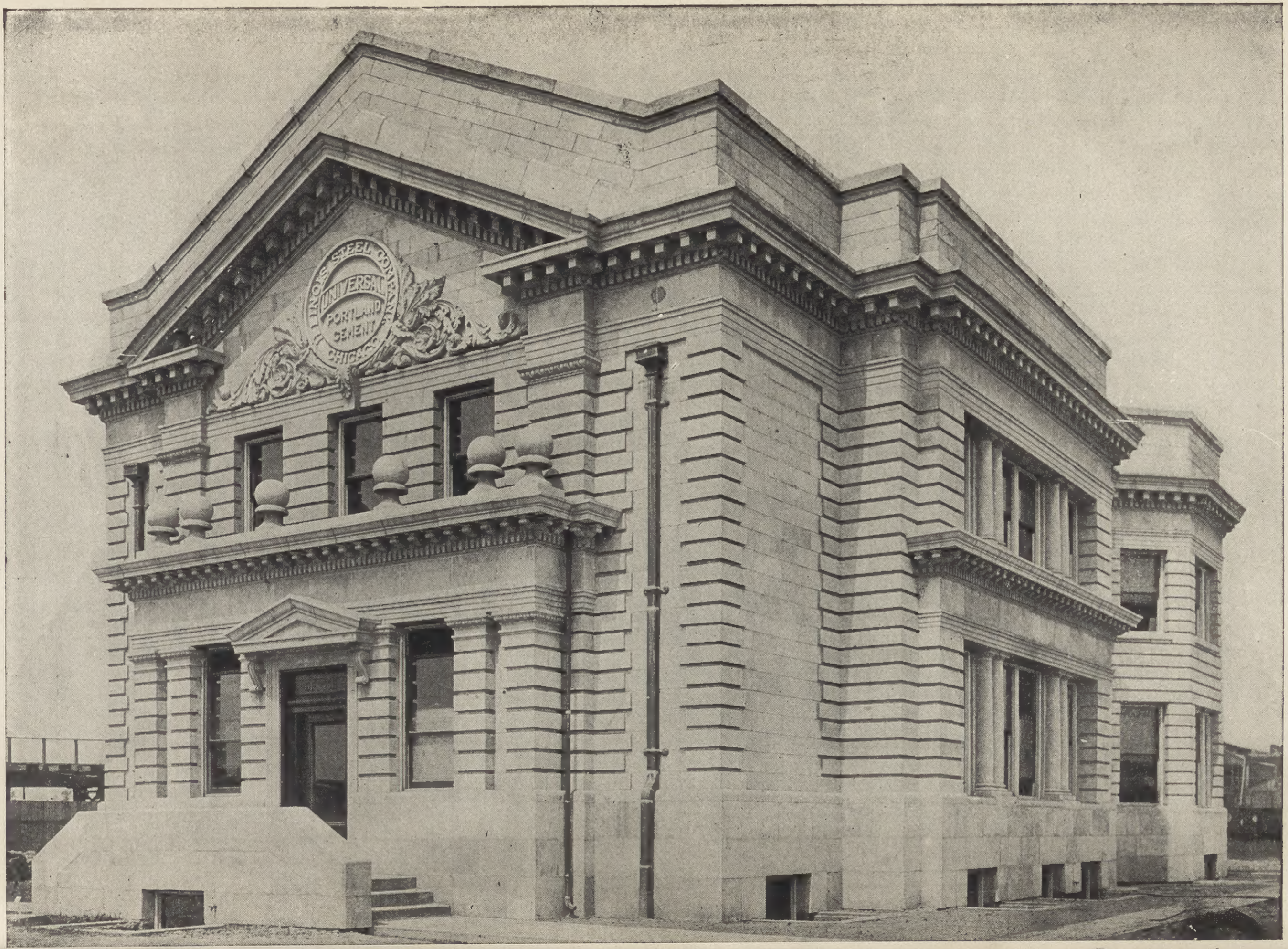

Frontispiece — Office Building of the Buffington Cement Plant of the Illinois Steel Co. — *By courtesy of*

CONCRETE-BLOCK MANUFACTURE

PROCESSES AND MACHINES

BY

HARMON HOWARD RICE

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PREFACE.

The object of this book is to present in a simple manner those well-established principles of concreting which practice has shown applicable to the manufacture of concrete blocks for building hollow walls.

The theoretical and technical questions which arise in connection with the industry are only considered in so far as benefit may result to the operator in the actual manufacture of blocks and their use in construction.

The conclusions which have been reached are the result not only of the author's experience in actual work, but of a careful consideration of the successes and failures of a large number of operators throughout a series of years, supplemented by a careful weighing of the many articles bearing on particular phases of the subject which have been published in cement, engineering, and building magazines.

To many it will appear that this book is unduly critical. For this no apology is offered. As the industry grows much of the evil herein criticised will pass away, and it is hoped that this work may, in some measure, aid in giving to the weaknesses of the industry that prominence which can alone secure their eradication, to the end that concrete blocks may universally attain that high regard now accorded in localities where they are manufactured by really able hands.

As no allusion to patents is made in the text, the author deems it but fair to here state that very many of the designs and machines shown are protected by letters patent.

To those manufacturers whose ready cooperation has been both a powerful stimulus and a substantial aid in the production of this work grateful acknowledgment is rendered. To those who have so generously furnished illustrations of the machines they make, and of the buildings, blocks, and special members produced in machines or molds of their manufacture, the author's thanks are due. This list is as follows: The Winget Concrete Machine Co., Columbus, Ohio, Figs. 11 and 18; The Cement Working Machinery Co., Detroit, Michigan, Fig. 44; Kells' Foundry and Machine Co., Adrian, Michigan, Fig. 5; Miracle Pressed Stone Co., Minneapolis, Figs. 10, 13, 38, and 39; H. S. Palmer Hollow Concrete Building Block Co., Washington, D. C., Figs. 3, 14, and 15; J. B. Prescott & Son, Webster, Massachusetts, Fig. 40; White Cement Machinery Co., Jackson, Michigan, Fig. 43; The Hayden Automatic Block Machine Co., Columbus, Ohio, Figs. 17 and 34; Contractors' Supply and Equipment Co., Chicago, Fig. 1; Municipal Engineering and Contracting Co., Chicago, Fig. 2; Ideal Concrete Machinery Co., South Bend, Indiana, Figs. 28, 30, 31, and 35; Simpson Cement Mold Co., Columbus, Ohio, Fig. 45; The American Hydraulic Stone Co., Denver, Colorado, Figs. 6, 7, 8, 9, 12, 19, 21, 23, 24, 25, 27, 29, 32, 33, 36, and 37; The Pettyjohn Co., Terre Haute, Indiana, Figs. 16, 22, and 26; Concrete Block Machine Co., Auburn, Indiana, Fig. 4; Century Cement Machine Co., Rochester, New York, Figs. 41 and 42; Chase Foundry and Manufacturing Co., Columbus, Ohio, Fig. 20. The frontispiece is presented by courtesy of *The Cement Age*, New York.

HARMON HOWARD RICE.

DENVER, COLO., March 1906.

CONTENTS.

CHAPTER I.

CONCRETE.

CHAPTER II.

CEMENT.

CHAPTER III.

AGGREGATE.

CHAPTER IV.

WATER.

CHAPTER V.

OTHER INGREDIENTS.

CHAPTER VI.

PROPORTIONING.

CHAPTER VII.

MIXING.

CHAPTER VIII.

SHAPE OF BLOCKS.

CHAPTER IX.

PROCESSES.

CHAPTER X.

PLASTICITY.

CHAPTER XI.

FACING.

CHAPTER XII.

ORNAMENTATION.

CHAPTER XIII.

CURING.

CHAPTER XIV.

MACHINES.

CHAPTER XV.

PLANT ARRANGEMENT.

CHAPTER XVI.

PLANT EMPLOYEES.

CHAPTER XVII.

VOIDS.

CHAPTER XVIII.

QUALITIES OF CONCRETE BLOCKS.

CHAPTER XIX.

TESTING BLOCKS.

CHAPTER XX.

BLOCK USES.

CHAPTER XXI.

CAUSES OF FAILURE.

CHAPTER XXII.

COST.

CHAPTER XXIII.

ARCHITECTURE.

CHAPTER XXIV.

BUILDING CONSTRUCTION.

CHAPTER XXV.

BUILDING REGULATIONS.

CHAPTER XXVI.

MANUFACTURE OF ACCESSORIES.

ILLUSTRATIONS.

CONCRETE-BLOCK MANUFACTURE, PROCESSES AND MACHINES.

CHAPTER I.

CONCRETE.

One of the greatest difficulties encountered in the introduction of concrete blocks has been ignorance of the character of concrete, its ingredients, its qualities, its uses, and its limitations. It is scarcely necessary to dwell upon the importance of this knowledge to those in any manner interested in concrete blocks.

Concrete may well be defined as a hard, stone-like mass resulting from the mixture of aggregates of various nature and size with a cementitious substance possessing sufficient hydraulicity to become thoroughly indurated by the addition of water. It will therefore appear that there is a wide range of variance as to the bonding material, as to the aggregate, as to proportions and manipulation of the mass, as to methods of condensation and curing, and as to form, size, and shape of the resulting construction.

In modern practice in the United States, concrete has been limited to the use of various aggregates with hydraulic cements;

and the aggregates have usually been limited to such materials as sand, gravel, stone, or cinders. In ordinary concrete-block work, this limitation is carried still further, especially as prohibiting the use of other than Portland cements.

The general theory of concrete involves the thorough coating of the larger particles of the aggregate with sand and cement mortar, and the coating of the smaller particles with neat cement paste, so that all are thoroughly bonded together by the crystals formed in course of the chemical action resulting from hydration of the cement. It is therefore apparent that cement is the vital element in the production of concrete; that the quantity of water and the time and method of its application are of importance; and that the qualities of the concrete are largely governed by the character of the aggregate and by its quantity as related to the cement, and also by the relative quantities of the different sizes and kinds of aggregate as related to each other. The mechanical factors of manipulation in mixing, of methods of depositing and compacting, and of maintaining proper conditions to secure thorough crystallization in the final set, are not of less value.

The multitudinous uses of concrete have developed from its plasticity, and the consequent ease with which it assumes any desired form. It would be somewhat aside from the intent of this work to speak of the uses of concrete outside of walls and the construction of buildings, especially as these afford ample proof of its adaptability, it being now generally utilized, either plain or reinforced, for every member of high-class construction.

From the dams, reservoirs, and retaining-walls of railroad and government engineers it was an easy step to monolithic building construction, and it is to its success that the development of block construction is due. The major portion of the expense, in connection with plain concrete walls built in place,

lies in the construction of forms and the handling of the concrete, while the difficulties attendant upon securing a satisfactory surface have led to the use of veneering for structures of the better class. To obviate these difficulties, concrete blocks were brought forth, which might be constructed in factories equipped with suitably designed molds and appliances for manufacture under conditions calculated to secure the best results by adherence to the demands arising from the inherent qualities of concrete in plastic form. Thus the abnormal expense incident upon the labor of taking down and resetting forms, and of depositing the concrete, is eliminated, and in its place is the small labor cost of a well-equipped and thoroughly systematized factory, while the compacting of the mass is greatly facilitated and the important item of curing, entirely absent in monolithic work, is a matter of easy accomplishment. Block manufacture also opens an illimitable field in decorative art, and the fact that it has thus far fallen into incompetent hands does not diminish the ultimate advantage.

The greatest relative advantage of concrete blocks lies in the use of shapes resulting in hollow walls; and it may hereafter be understood that any reference to concrete blocks, not otherwise specifically qualified, shall be taken to mean either blocks containing one or more hollow spaces or blocks of such shape that their combination in a wall will produce hollow spaces therein.

CHAPTER II.

CEMENT.

THE history of hydraulic cements is a matter of great antiquity, as some combination of materials properly classed under this heading was evidently known to the ancient Egyptians, and employed by them in the massive structures testifying to their genius in structural engineering.

It is, however, more customary to date the discovery of the principle of hydraulic cements from the time that the Romans mixed puzzolana with lime, and demonstrated that a mixture of burned clay and lime resulted in a material which would crystallize, or set, upon the application of water. This fact is so well authenticated that when, after a lapse of centuries, Mr. James Parker discovered in the Isle of Sheppey natural materials of composition suitable for the production of hydraulic cement, that cement came to be called Parker's or Roman cement. The development of the Portland cement industry followed as the attention of engineers was drawn to its possibilities, and as chemists discovered the requisite constituents and the natural materials in which those elements occur in form most available for cement manufacture.

Puzzolan cement derives its name from the ancient cement of the Romans. It properly includes cement made by grinding together, without subsequent calcination, a mixture of hydrated lime and such other material as slag, burned clay, or trass obtained from volcanic tufa. In American practice, however, the ingredients of Puzzolan cement are limited to hydrated lime and

granulated blast-furnace slag. It is no longer called "slag cement," for the reason that, in the manufacture of certain brands of true Portland cement, furnace-slag is used as a hydraulic base. The point to be borne in mind in reference to Puzzolan-cement manufacture is that the materials are not calcined after mixing. They are, however, ground to extreme fineness, and, as the lime is prehydrated, but little water is required in mixing concrete. Puzzolan cement is of a light-lilac color, of a lower specific gravity than Portland, and the presence of sulphides produces a green color in the fracture of a pat which has been long under water. While its tensile strength may approximate that of Portland, its strength under compression is much less. It is not suitable for any use in dry places or above ground, as oxidation results in cracks and disintegration; and it is therefore evident that, for the ordinary service demanded of concrete blocks, it is manifestly unfit.

Natural cement is, as its name implies, produced from natural cement rock found in various sections of the United States, and is the same as the Roman cement of England. The analyses of cement rock vary greatly in different localities, and even in adjoining sections in the same district. In some cases it approximates rather closely the requirements of the raw materials for Portland-cement manufacture, while in some factories two or more kinds of rock are mixed, but without that definite chemical analysis obtaining in the manufacture of Portland. The process of manufacturing natural cement does not involve so high a temperature in the kiln as in the case of Portland, the calcination merely sufficing to liberate the carbonic-acid gas. Consequently the clinker is more easily ground; and for this purpose burr-stones were formerly universally employed, although some factories have recently installed grinding-machinery of similar type to that used in Portland mills. Natural cement

is well adapted for use in the interior of heavy masonry, where the concrete will not be subject to attrition or blows; but good practice demands that a larger proportion be used than would be required of Portland, and the question of determination as between the use of the two becomes, in such cases, an economic problem. It is apparent that it is not suited for concrete-block work, as the severe service demanded of the blocks in general construction, and the desirability of providing a large hollow space by making face-sections as thin as consistent with safety, requires a cement beyond possible criticism or doubt.

Portland cement is produced by intimately mixing or grinding together definite proportions of argillaceous and calcareous substances, usually 75% of the former and 25% of the latter, burning this material to semifusion and grinding the resultant clinker to an impalpable powder. The features which distinguish Portland cement from all other cements are the intense heat at which the pulverized raw materials are calcined, and the accurate proportioning of the essential elements entering into its composition. These elements are lime, silica, alumina, and oxide of iron, and there must be in the finished product not less than 1.7 times as much lime by weight as of the other elements mentioned. These elements are found in various materials, and the following classification includes all raw materials commonly employed:

Calcareous Materials.	Argillaceous Materials.
Limestone.	Cement Rock.
Marl.	Clay.
Chalk.	Shale.
	Slag.

The raw materials were formerly ground between burr-stones, which have been generally replaced by ball- and tube-mills,

Griffin or Kent mills. The grinding of the materials to extreme fineness before calcination is one of the greatest factors in successful cement manufacture; and in this connection, as well as in the grinding of the clinker, the Griffin mill, which operates on a principle similar to a gyratory crusher, has been a distinct factor in the development of the Portland-cement industry. After grinding, the material is again sampled and chemical analysis made. When the prescribed proportions have been obtained, the material is fed into a long rotary kiln, into the lower end of which the fuel is introduced. The revolutions of this kiln, the injection of fuel and the feeding of the charge being under the direct control of the operator, insures a product of such uniform excellence as could not be approached under the burning in intermittent dome-kilns or continuous vertical kilns formerly in vogue. Indeed, it may be said that to the rotary kiln, more than to all else, is due the remarkable growth in the manufacture of American Portland cements, the increase in their quality and uniformity and the decrease in their cost. From these long kilns the clinker is delivered in particles about the size of peas; and it is a fact worthy of notice that these particles are inert, for it accentuates the later observation that the hydraulicity of cement increases with fineness of grinding. By means of grinding-machinery already mentioned, this intensely hard clinker is reduced to the Portland cement of commerce.

The wet process formerly differed radically from the dry, and involved the formation of slurry bricks, which were then introduced into kilns of a style no longer in use. At the present time, however, the difference between the two processes in the United States only involves mixture of marl and pulverized clay in pug-mills or edge-runners, with subsequent grinding in wet tube-mills, after which the process is continued as already described.

The extreme care exercised in the manufacture of standard brands of American Portland cements, the large number of factories operating in all sections of the country, the enormous increase in production and consumption of the product and its satisfactory use in the most important work of government and railroad engineers, leave no room for doubt as to its adaptability for the highest class of concrete-block construction, and afford no excuse to those who refuse to abandon the prejudice which favored European brands in the days of the infancy of this great American industry.

Of the standard tests for cement, that of greatest importance to the concrete-block manufacturer is the test for constancy of volume; and it especially commends itself because requiring no apparatus other than a glass molding-board and pieces of glass on which the pats may remain during the period of test. Circular pats should be formed three inches in diameter, a half inch thick at the center and tapering toward the edge. After remaining in thoroughly moist air for twenty-four hours, one should be steamed for about four hours. This is called an accelerated test, and tends to quickly develop any imperfections. It is usual to specify that, in case of failure in the accelerated test, the cement may be again tested twenty-eight days later, as it may withstand this severe test when properly aged. Another pat should be exposed in moist air, and still another immersed in water, results being noted in the latter two cases at intervals during twenty-eight days. If the cement be sound, it should not disintegrate, or show expansion cracks in the edge of the pat. A slight curling of the edge is not harmful in the air specimen, but should not occur in one immersed in water. Shrinkage cracks on the center and hair cracks on the surface are commonly, in neat cement-work, the result of careless manipulation, excess of water, or too rapid drying, and may be disregarded in the test.

CHAPTER III.

AGGREGATE.

The inert coarse material which, in combination with cement and water, produces concrete is termed the aggregate, and is divisible into fine aggregate of sand or stone screenings and coarse aggregate of gravel, broken stone, or cinders.

The mineralogy of sand has but slight effect upon its combination with cement, and the best authorities consider it of so much less importance than the physical properties that it may safely be passed without discussion.

The shape of grain has been carefully considered, and while some tests appear to show as great strength in round grains as in sharp, and while satisfactory work has been done with sand of rounded grains, the best engineers continue to specify that sand shall be sharp. Where local conditions admit of choice between the two, the sharp sand should, other qualities being equal, invariably be selected. The strength and firmness of the grains is an item of much importance; and perhaps the best method of choosing sand is to determine its firmness and grit by rolling in the palm of the hand or between the fingers, meanwhile applying considerable pressure. Another excellent method is to test the sand for absorption. This cannot be accomplished in the manner of usual percentage tests, as the capillary attraction between grains will take up a considerable amount of water, even though the sand be practically non-absorbent. The proper

way is to let the sand soak for an hour, and then examine it in the manner already mentioned for firmness and grit. A sand which shows the slightest tendency to dissolve or soften under such treatment should be discarded.

The sand should be clean, and free from foreign matter of every kind. In general concrete work there has been a disagreement among engineers as to the permissibility of a certain percentage of loam or clay, and some have claimed that it increased the strength of the concrete. A careful consideration of such reports, supplemented by exhaustive tests, has established the fact that such reported increase in strength only obtains in lean concrete of porous texture in which the voids are not properly filled, and that, in every case of reasonably rich concrete of such density as required in concrete blocks, strength is lost by such admixture. The object of this work is to raise the quality of concrete blocks in every possible manner, and it is therefore recommended to every concrete-block maker that sand, which in its natural condition contains any foreign matter, be washed until the water is no longer discolored.

The most important consideration in connection with the selection of sand is the size and gradation of sizes. In this respect the inexperienced block-maker often commits grave error by the selection of fine sand, erroneously supposing that it contains a smaller percentage of voids, and hence hoping to obtain greater strength by use of stated proportions. As a matter of fact, the percentage of solids in a perfectly dry mixture of fine and coarse sand, both shaken to refusal, is approximately the same, and any difference is due merely to shape of grain; but, upon the addition of water, the volume of the fine sand increases in greater ratio than the coarse, because there are more grains between which the water is introduced, and therefore a fine sand becomes distinctly more porous than a coarse

sand. In the same manner it will be seen that, by mixing cement-paste with sand until every grain is thoroughly coated, a much greater proportion will be required for fine sand than for coarse. The best results are obtained by mixing coarse and fine sand in such sizes and proportions that the finer grains tend toward filling the voids in the coarse sand, thus securing a maximum density with a minimum quantity of cement.

It has been stated by eminent authorities that crusher screenings give greater strength than natural sand, and tests have generally shown results in accordance with this statement where the stone from which the screenings came was of proper texture. This doubtless results from the variation in the size of screenings, which are not nearly so uniform in size as are the grains of the average natural sand, and thus the screenings accomplish to a certain extent the same result obtained by a careful mixing of graded sand.

For the coarse material of the aggregate, gravel is commonly used where locally obtainable at a reasonable price. It should run in size from a quarter inch to as large pieces as can be conveniently accommodated in the block mold. Usually from $\frac{3}{4}''$ to $1''$ should be the maximum for concrete-block manufacture, and the principles of gradation already stated for sand must be observed in the use of gravel. A great deal of time has been spent in discussing the relative merits of gravel and broken stone, and tests appear to show greater strength on short-time tests of stone concrete than of gravel concrete, while tests extending over long periods of time show little difference. It is questionable whether the results of such tests may not be influenced by considerations other than the mere use of gravel or stone, such as the relative sizes of aggregate or hardness of the stone used.

It must be remembered, in employing broken stone as a

concrete-block aggregate, that concrete will not possess strength in excess of that of its aggregate, and hence soft sandstones or the softer limestone formations should not be used. A hard limestone, however, is a very desirable aggregate, and is largely employed in general concrete work by railroad engineers. Conglomerate rock makes good concrete, while granite and trap-rock are the best that can be obtained.

Cinder concrete has often resulted in failure, and, while its light weight commends it for partition-walls, its use cannot be generally recommended, and never in any place where its failure would jeopardize the integrity of other members of the building.

CHAPTER IV.

WATER.

WATER is the chemical agent which unites with the cement, and results in that crystallization of the silicates which is commonly known as the setting of the cement. Both in the initial and final sets, there are certain scientific principles relative to the application of water which have been abundantly demonstrated in actual practice.

The first consideration is pure water. Neither muddy water, stagnant water, water impregnated with alkali, nor water discolored by the refuse from factories, sewers, reduction-works, or the like, will give the best results. The matter of water, both pure and clean, has been generally disregarded; but it is of so great importance as to justify consideration in the location of a plant, as well as some expense in its equipment.

The quantity, method, and time of applying water has been grossly disregarded, and it is to the haphazard methods of using water that much of concrete-block failure is justly chargeable, It is impossible to overestimate the importance of using in the mix an amount of water sufficient to reduce the cement to such plasticity that, with reasonable manipulation, it will thoroughly coat the particles of the aggregate. No good concrete can be produced in any other manner; and it is a fact worthy of note that concrete engineers have generally abandoned the dry mix-

ture of bygone days, and the old specification of a "damp-earth" consistency is now universally replaced by a "quaking" mixture. The application of water should always be in a manner which will not wash the cement from the aggregate; and the quantity should not be so copious as to cause decomposition by "drowning" of the cement, or to cause hair-cracks by flushing neat cement to the surface.

Relative to the matter of curing, it may be here noted that concrete blocks possess a distinct advantage in the opportunity offered of thorough induration before going into the wall. Many feel that the hardening of a block after making is a matter requiring no thought and no skill. It is in reality the critical time in the making of a block; and the best thought of the manufacturer of blocks may well be given to the details of method, time, and quantity in relation to the application of water to the blocks after they come from the molds, and before they leave the curing-yard.

In winter work, the mixing-water is often heated and results are very satisfactory, especially if the aggregate also be heated. It is, of course, evident that the time allowed for setting of the cement before suspension by freezing is thus greatly lengthened, while it has been amply demonstrated that crystallization is accelerated by the use of hot water. However, under ordinary conditions of operating a block-machine in a closed building where the sand-bins are sufficiently warmed by artificial heat to drive out the frost, it is scarcely necessary to incur the extra expense of heating water.

In freezing weather, salt is often added to the water used in mixing concrete, and the use of a reasonable amount causes no loss in strength. Various formulas have been devised in the nature of a sliding-scale based on the registered temperature, but none of these appear to be of great practical value. All are

based upon a certain percentage of the water by weight. It is evident that, by the common rule of using 1% of salt for each degree registered below 32° F., the quantity would, in zero weather, be excessive. Tests have shown that 10% of salt is not injurious.

CHAPTER V.

OTHER INGREDIENTS.

VARIOUS other ingredients are used by certain block-makers in addition to those mentioned in preceding chapters. In general, it may be said that the admixture of any other substances should be regarded as adulterations and viewed with suspicion until tests and actual service have demonstrated not merely usefulness for a specified purpose, but the fact that no deleterious action on the cement results, as well as the permanence of the added material in relation to the life of the cement.

The use of lime in concrete blocks has of late received much attention. It is well known that unslaked lime is eminently unfitted for such use, as hydration greatly increases its bulk, and hence only slaked lime has been employed. There are, however, unslaked particles in every lime-bed, and, even though, as in Germany, the lime be allowed to slake for months before using, this criticism remains true to a greater or less degree. It is evident that, with the thorough mixing of well-made concrete and with the subsequent saturation of the block during the period of induration, any such particles are liable to cause trouble by swelling, producing expansion cracks, and resulting in possible failure of the member through disintegration.

The block-makers favoring the use of lime have therefore adopted the slaked and sifted powder offered commercially

under the name of "hydrated lime." Being comparatively new as a commercial product, it is difficult to say what may be considered as standard practice in its manufacture. There appear to be two principal methods in use. The first consists in the use of a hooded pan-mixer into which the lime, previously broken in a crusher or gound in a tube-mill, is fed, and, as the mixer revolves and the water is supplied by automatic sprayer, the mass is thoroughly agitated by paddles, reducing the slaked lime to powder, which is afterward screened, the screens often being as fine as those used in cement-testing. The second process involves the use of a rotary cylinder of design somewhat similar to the kilns used in cement manufacture, the moisture being supplied by a perforated steam-pipe forming the axis, and the slaked lime passing through graduated screens, so that it cannot pass a given section of the cylinder until the required fineness be attained. It is therefore evident that this thorough process of hydration and pulverization leaves nothing to be feared, except that the life of the lime is less than that of the cement. Even this doubt seems unwarranted, in view of the extreme fineness of the particles, and the fact that, although there may be a slight chemical action between the lime and cement, the latter hypothesis is not well established, and lime is employed merely on account of its capacity for filling voids. In this respect it has shown great merit, both in the increase of water-tightness and in greater strength of lean concrete. It is, of course, evident that hydrated lime is of distinctly less value in a rich and carefully graded concrete, in which the voids are well filled, than it is in a lean and porous concrete. In the latter it becomes, unquestionably, an agent for good, both as to density and compressive strength, unless the ease of filling voids by its use tempt the block-maker to carelessness in gradation of aggregate, to an unwise economy in the proportion of

cement, and to the use of an unreasonably large proportion of slaked lime. Ordinarily the amount of cement by weight should be at least four times that of hydrated lime.

It has been too customary in the earlier stages of the industry for block-makers to modify the natural action and qualities of cement by the addition of various chemicals. It may be set down as a general rule that all such adulteration violates fundamental principles of good practice, for the reason that the composition of standard brands of American Portland cements is determined by the most careful chemical analysis, and the formulas, after the most exhaustive experimentation, have been prepared with the object of producing cement which shall meet the requirements of those tests specified by the American Society of Civil Engineers and the American Society for Testing Materials. Gradually are the operators of block-machines learning that no adulteration can secure an ultimate gain in strength, and that the gain in ease of manipulation which may result from a change in the normal time of setting is no adequate compensation for jeopardizing the permanent strength of an otherwise durable building material.

Of the various benefits which have been claimed for the addition of chemicals, perhaps water-tightness is the most common, both as to known chemicals and as to compounds of unknown ingredients. It may be said, to the credit of a large number of operators, that they prefer the additional labor and care necessary to produce an impermeable block by natural methods, rather than the easier way of securing similar results, but short-lived blocks, by chemical admixture to a poorly graded and carelessly manipulated mixture.

The addition of various materials for coloring purposes has been considered, by nearly every writer upon concrete blocks or concrete building construction in any other form, a matter

of sufficient importance to justify a tabulated statement of substances and quantities suitable for producing different colors. Superficial study of such tables will show a discrepancy so marked that their worthlessness for practical purposes becomes apparent. It is evident that any such table can only be applicable to a particular aggregate, and that a change in local materials will necessitate an entire readjustment of quantities. It is particularly noticeable that each one advocates one or more of the coloring materials as harmless, while another author is equally sure of deteriorating influence. The fact is that every one of these artificial colors causes loss of strength. To be sure, other things than strength require consideration, and a customer may in rare cases be willing to waive slight reduction in strength and durability to attain certain artistic color-effects. If it becomes necessary to employ artificial colors, it is a wise course to procure them from a reputable concern whose energies are entirely devoted to the production of mineral colors for concrete under the most favorable conditions. Every effort should be used to obtain for the aggregate crushed rock of the required color, as in this manner it is possible to produce blocks of any color which a reasonable customer may demand, and the purity, strength, and durability of the concrete is in no wise impaired, while the blocks are saved from that artificial and plaster-like appearance which too often obtains in colored work. Most operators have not yet learned that the sensible place to regulate color is in the selection of aggregate.

CHAPTER VI.

PROPORTIONING.

By the usual method of expressing proportions in cement work, 1:4 represents one part cement to four parts sand; while 1:2:4 represents one part cement, two parts sand or screenings, and four parts gravel or broken stone.

The relative proportions requisite to secure the greatest density, strength, and impermeability—in short, to make the best concrete blocks—are not the same in various localities because of the diversity in locally available materials. It has been the custom of most manufacturers of machines to adopt an arbitrary standard of proportions, based upon the results of their own tests and experiments; and, while these proportions have been substantially correct for a particular class of materials, it by no means follows that they are correct for other classes available in different localities. It has often been the case that an operator, closely following the advice of his machinery salesman, has produced very bad blocks from very good material, and has either failed utterly or learned by experience that the conditions under which he worked demanded a local remedy.

The importance of ascertaining correct proportions for the particular materials in use cannot be overestimated, and all block-makers should have the correct proportions of the materials they purpose using determined by expert tests. The expense of such tests is really an economy, as the result is such careful

gradation of the aggregate that maximum quality is secured with a minimum quantity of cement. As many will not, however, be able or willing to avail themselves of such expert tests, some elementary methods of determining proportions may be helpful.

Proportioning involves primarily the use of the greatest possible quantity of as large aggregate as can readily be manipulated in the particular type of machine in use, and the addition of a series of smaller sizes of aggregate in quantities sufficient to fill the spaces between the pieces of each successive larger size of aggregate. As each piece of the aggregate must be coated with cement-paste, or with sand and cement mortar, it is evident that filling the spaces between pieces of large-size aggregate with fine sand involves the use of an unnecessary amount of cement. It is equally clear that, if the smaller aggregate be too large for its intended purpose, or used in too great quantity, the larger aggregate is forced apart. In either case a loss of strength or a waste of cement results. It is clear that this gradation may be continued indefinitely, and that any attempt to determine proportions of a mixed aggregate can give no definite information unless the aggregate be screened until each sample is within such range of screen as to be of practically uniform size. The matter is then resolved into determination of voids in the larger size which may be filled by the smaller size. In practice, the impossibility of securing an absolutely ideal mixture of materials has led to the customary addition of 5% to the determined amount of sand or screenings, and 10% to the determined amount of cement.

Specific gravity affords an accurate method of determining the percentage of voids, and the consequent amount of material required to fill them. As obtaining the specific gravity of a particular substance requires apparatus not usually found in a concrete-block factory, the technical part of this test may

be dispensed with by assuming the weight of a solid and unbroken cubic foot of sandstone to be 150 lbs., of trap-rock 180 lbs., and other stone of intermediate weights, while sand and gravel may be safely estimated at 165 lbs. The aggregate of which it is desired to determine the voids should be dried to a constant weight, and shaken to that degree of compactness which it is expected to attain in the finished block. By subtracting the weight of a cubic foot of the aggregate in this condition from the weight of a solid cubic foot, as above estimated, and dividing the remainder by the weight of a solid cubic foot, the result will be the percentage of voids.

Another method commonly employed, but less accurate, is that of pouring a measured quantity of water into the aggregate, and determining the percentage existing between the measure of aggregate and the measure of water. It is evident that if the aggregate be dry it will absorb a certain percentage of the water, and if it be wet the particles are separated by water tension. It is a speedy method where hasty determination is necessary, but should always be considered approximate, and subject to verification by more accurate methods.

Determination by relative volume is doubtless the most practical method of proportioning, and is of especial value when used as a check upon the last-mentioned test. A known weight of dry-mixed aggregate and cement in supposedly correct proportions is placed in a vessel, shaken to refusal, and the height marked. Equal weights of slightly different mixtures are then deposited in the vessel in like manner. It is evident that the mixture attaining the smallest volume possesses greatest density.

It must not be forgotten that all of these tests are equally applicable to fine and coarse ingredients, and the operator is compelled to rely on his own judgment as to what shall be the maximum size used in his aggregate. This is a matter of great

importance, as tests show conclusively that strength is greatly augmented by admixture of coarse gravel or broken stone, while it is not hard to see the rapid increase in density and the marked saving in cement which result from the introduction into a fine mixture of a considerable amount of coarser aggregate.

The customary manner of specifying proportions by volume is inaccurate and misleading. There is a marked difference in the volume of a given weight of cement packed and the same weight loose. The volume of sand increases with the addition of moisture, owing to water tension between the grains, and the volume of fine sand increases under such conditions more rapidly than does coarse. The relative weight and volume of gravel and broken stone vary greatly, being lighter when the particles are of uniform size and heavier when they are correctly graded. Proportions should, therefore, be stated by weight in all cases where accuracy is desired.

CHAPTER VII.

MIXING.

THE incorporation of the various ingredients of concrete into a homogeneous mass, the manipulation of the mass until its constituents are uniformly distributed, and that extent of turning and stirring necessary to secure an even percentage of moisture throughout the whole, constitute essential factors of success or failure in concrete-block manufacture. Indeed, in all concrete work, mixing is a feature so essential that its neglect entails failure, while a recognition of its importance oftentimes averts the failure that might be anticipated from negligence in other branches of the process of concreting. This importance is accentuated in concrete-block work, because the duty required of the blocks, in proportion to the bearing area of solid material therein, requires a uniform strength and density, which is, in other forms of concrete work, to a certain extent overcome by the volume of material, and the support afforded by the adjacent mass of material. Further than this, those peculiar qualities of impermeability, uniformity of color and beauty of decoration, are demanded in block work to a far greater extent than required in the classes of construction to which monolithic work is especially adapted. It is only by most thorough manipulation that these qualities may be developed in satisfactory degree. Indeed, in relation to strength, and to a certain extent in relation to the other qualities mentioned, a careful attention to mixing

may serve to greatly overcome faults arising from ignorance of other scientific principles of block-making, or from carelessness in the application of those principles. While by no means encouraging the use of lean mixtures, while thoroughly cognizant of the importance of correct proportioning, and while advising the strictest adherence to other well-determined essentials as outlined in other chapters, the facts must be recognized as established by those tests which have proven that a thoroughly mixed lean concrete, and even a thoroughly mixed ill-proportioned concrete, affords results more satisfactory than a rich and well-proportioned concrete of indifferent mixing. The reason is easily found. It has already been said that the theory of concrete involves the thorough coating of every fine particle of the aggregate with cement-paste, and the coating of every coarse particle of the aggregate with sand and cement mortar. It is evident that this can be accomplished in no other way than by most thorough mixing. It has also been said that the theory of proportioning involves such gradation of aggregate that the finer particles will tend to fill the voids of the succeeding larger sizes. It is evident that nothing but mixing can attain this desirable result, as faulty mixing will leave the various sizes of aggregate, as well as the aggregate and the cement, each gathered to itself, instead of becoming distributed evenly throughout the whole.

The order of incorporating ingredients has been considered a matter of so great importance that it is particularly mentioned in all standard concrete specifications, although the practice of most cement-block makers is to disregard any particular order and dump cement, sand, gravel, and water together indiscriminately. In hand-mixing under railroad, municipal, or government specifications, predetermined quantities of the various sizes of aggregate are measured in boxes having no bottom or

top, so that when the box is filled it may be lifted from the measured material. The sack is the unit of cement measurement. The required amount of sand is first spread on the mixing-platform, which should be water-tight and, if possible, non-absorbent. The cement is then spread to an even thickness on the sand, and the two, by means of hoes or square-pointed shovels, are turned together two or three times, or until of an even color, when the water is either sprayed on the mixture from a hose-nozzle or poured (but not dashed) into the center of the material previously thrown into the form of a ring or crater. The latter method is considered better practice, as affording accurate measurement of water. The mixture is then turned twice, the percentage of water being such as to form a rather wet mortar. The gravel or broken stone, previously wet to avoid further absorption, is then spread on the mortar and the turning continued until uniform throughout the whole. It is evident that such careful methods secure the maximum quality possible for hand-mixing. It has, however, been the practice of block-makers to mix all materials dry and afterward apply the water, the latter usually being unmeasured, and then mix until approximate uniformity results. While the evils of this method are partially obviated by dry-mixing to secure uniform color before wetting, it is obvious that the degree of homogeneity possible by observance of standard specifications cannot obtain; and it is to this cause that weakness, porosity, permeability, and lack of uniformity in color are often traceable.

Hand-mixing is at best a method which should be employed only until the business of the plant warrants the installation of a good power-mixer, or upon special work in isolated localities which may not justify the full plant equipment. There are several reasons which should induce one, in equipping a plant, to include a power-mixer. The reduction in labor is a cost item

of great consequence, as one reason for defective hand-mixing is the large expense for labor necessary to secure really good results. The work done by power-mixing is not only vastly superior to hand-work in quality, but, if batches be run for equal periods of time, possesses the virtue of absolute uniformity. Actual tests upon hand- and machine-mixing show a gain in strength for the latter which fully justifies the initial outlay.

There are so many different kinds of mixers on the market to-day that the block-maker may err greatly in selection. The cheapest may prove most expensive on account of inefficiency, There are two classes of mixers which cannot be recommended for block work. The mixers operated by hand are but poor makeshifts, which scarcely give as good results for the same amount of labor as do square-pointed shovels. Of the power-mixers, the continuous type is not well adapted to block work, for two reasons. In the first place, too much depends upon the order in which the materials are introduced into continuous mixers, and therefore the materials must be spread in layers, in much the same manner as described in the preliminary operations of hand-mixing; and shovelfuls of material for deposit in the mixer must cut perpendicularly through the several layers, so that the shovel will contain the same relative proportions as desired in the mixed material. In the second place, the time of mixing is mechanically determined, and the manipulation cannot be increased even though the advantages of longer mixing may be clearly apparent.

The batch-mixers, operated by steam, gasoline engine, or electric motor, are especially adapted to concrete-block work, because the mixing may be continued at will, and thus any desired degree of uniformity is dependent only upon the time that the batch is run. Consequent upon this advantage is that other important consideration that the order in which the material is

discharged is entirely independent of the order in which it enters the mixer. Batch-mixers mix thoroughly, while the more com-

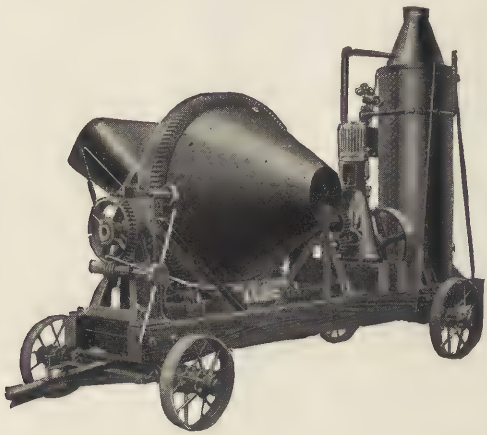

FIG. 1.—Rotary Mixer.

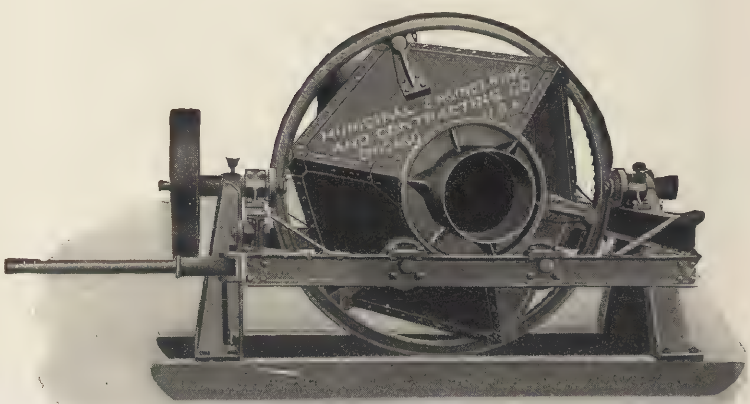

FIG. 2.—Cube Mixer.

mon forms of continuous mixers are modified conveyors, calculated to effect greater or less stirring of the material as it is

conveyed from entry to discharge. Fig. 1 shows a rotary mixer in which deflecting blades throw the material from end to end as the mixer revolves. Fig. 2 shows a revolving cube-mixer

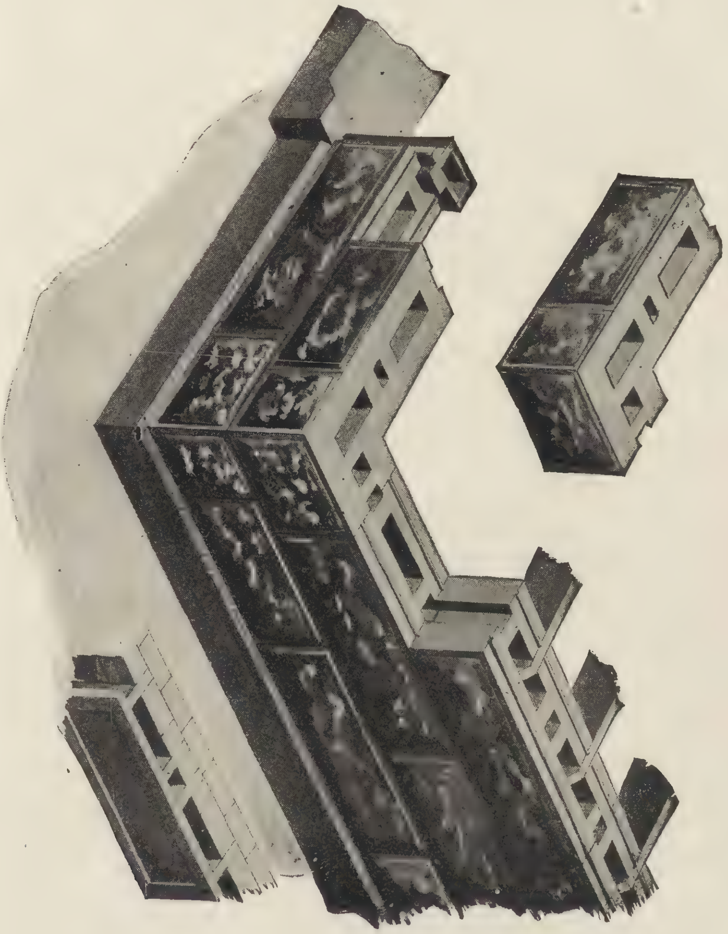

Fig. 3.—Hollow Blocks and Wall.

in which the shape of the mixing-box is relied upon to accomplish the same result without interior deflectors. Both of the types shown have given excellent satisfaction in actual use.

While, in using a mixer of a type similar to those illustrated, all materials for a batch may be put in at one time and no attention given to the order in which they are introduced, yet much better results will be obtained by running the batch dry until it is well mixed before introducing water into the mixer, and afterward running the batch wet as long as may be necessary.

Whether mixing be by hand or machine, it is essential that the initial set of the cement be avoided by so regulating the size of batch in proportion to the capacity of the block-machine that no cement will be wet over thirty minutes.

CHAPTER VIII.

SHAPE OF BLOCKS.

In considering the many shapes of blocks now used for forming hollow walls, the question naturally asked is, "Why so much talk of hollow walls, and what are their advantages?" In reply it may be said that the chief advantages of hollow walls over solid walls are four in number, viz.: Insulation against heat and cold, saving of material, water-tightness, and ventilation.

The fact that a considerable air-space between the face of a wall exposed to the weather and the interior face largely precludes the passage of heat has been too well established to admit of discussion. The result is, of course, that the rooms of a building are more comfortable in summer on account of the heat of the exterior surface not being transmitted to the interior, while in winter the conditions are reversed and the interior surface does not lose its artificial heat through transmission to the exterior. It is a fact that approximately 25% of heating-bills may be saved by properly constructed hollow concrete walls. A man who purchased a concrete-block house during the past summer, but who was not informed as to the real merits of this material, recently remarked: "The furnace in that house is a remarkably good one; it is surprising how small a fire makes the rooms comfortable." Doubtless it was a good furnace, but the reason of the noticeable warmth from a small fire was, that the heat

remained in the house instead of passing through a solid wall and disseminating itself throughout the surrounding country.

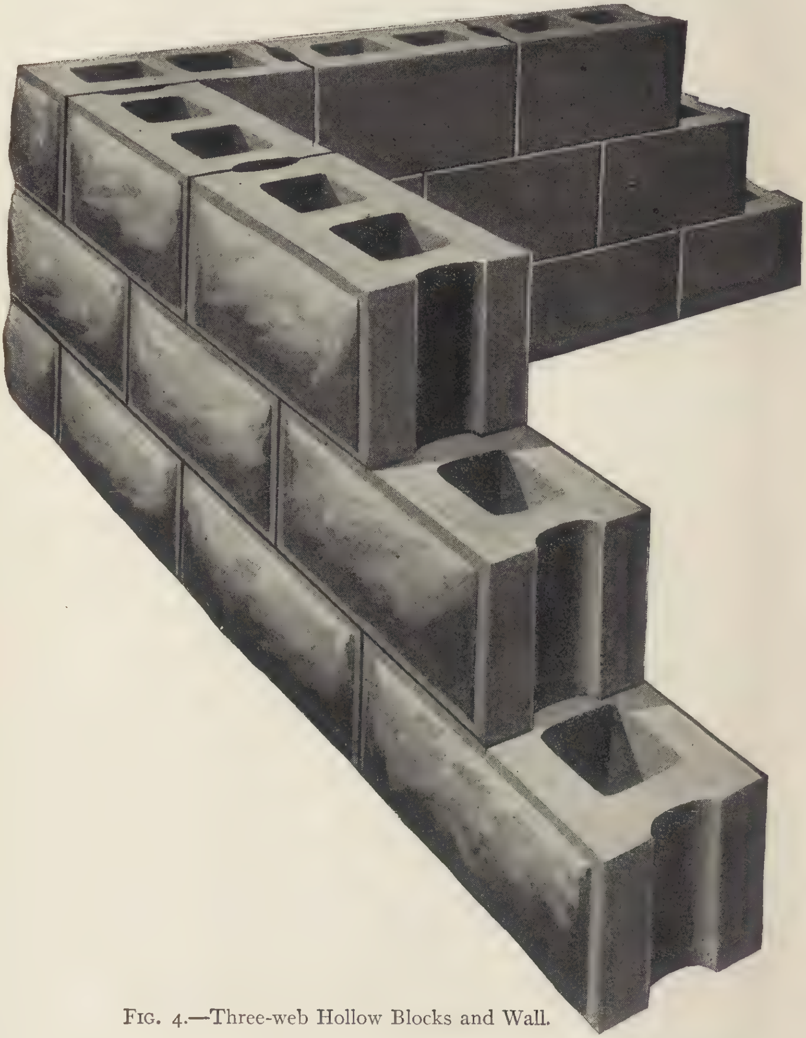

FIG. 4.—Three-web Hollow Blocks and Wall.

The saving in material is an important item to the block-maker and to his customer. In the hole in the wall lies the

maker's profit and the consumer's saving. Originally blocks were designed with from 20% to 33% air-space, but modern methods of proportioning, compacting, curing, and bonding have so greatly increased the efficiency of concrete blocks in relation to the actual amount of solid material that walls are frequently laid with from 50% to 55% of air-space, and still preserve a factor of safety which insures conservative construction.

The fact that concrete is not absolutely waterproof, and as commonly made is not approximately so, was doubtless one of the principal reasons for the original introduction of an air-space in the wall, the separation of the outer and inner face being designed to prevent water penetrating beyond the intermediate air-chamber.

Ventilation in the sense here intended is a consideration usually overlooked. It is, of course, well known that, by the use of ventilators similar to the usual hot-air register, any desired circulation of air may be established between the outer atmosphere and the air of a room through the vertical air-chambers in the hollow wall. This is, however, not the thought now in mind, but rather the gradual, unrecognizable, but nevertheless constant, absorption, through the pores in the concrete, of the dampness and injurious gases accumulating in every occupied room. It is the suction of the gases and vapor by the air in the wall that gives to block construction its great sanitary virtue, and hence the elimination of sweating on the interior is a noticeable feature of block construction.

In Fig. 3 is shown one of the earliest forms of hollow blocks introduced in the United States, a form which has been used in a very large number of buildings, a form which has been, with slight changes, adopted by very many manufacturers of machines, and a form which in its essential features stands for the hollow-block construction of to-day. It will be noted that the form is

very simple, having a transverse web at either end and two transverse webs midway of the block, so that a half block, which is an essential feature in all block construction, is made without change of cores. Special attention is called to the L-shape corner-block used in connection with this form, as some of the later types of hollow blocks eliminate this feature and merely use regular blocks extending through at corners, with the end web flush with the front and back of the block to form a corner return.

The block illustrated in Fig. 4 is not essentially different from that shown in Fig. 3, the only material variance being in the use of one intermediate web instead of two. Measured by the number of machines producing it, this is by far the most common type of block. There are at least twenty moulds and machines now advertised in trade-journals for making blocks with the three cross-sections by using two interior cores, and the type is common to upright and face-down machines.

The single air-space block, involving the elimination of the middle web and the use of but one interior core, is a later development, and hence less common than the form last mentioned. This block possesses some advantage, inasmuch as any reduction in the number and size of cross-partitions reduces the liability to penetration of moisture in case of heavy rains. It is also more easy to tamp around one core than to tamp around and between two or more, and hence, with the average grade of labor employed, a more thoroughly and uniformly compacted block will result. The releasing is also facilitated, and the danger of tearing blocks in removing cores is somewhat lessened, while there is a slight saving in material. This is a very simple form for those who prefer to make their own molds of wood instead of purchasing any of the standard machines. The author recently inspected, in the State of Washington, a $5,000 residence, nearing completion, in which all walls above ground-line were of this

type of block, made in wooden molds locally manufactured. The work was most creditable, but, in justice to those who may desire to go and do likewise, it should be said that the company building the house mentioned had in its employ a most expert model-maker and a cement-worker of equal ability.

Fig. 5 represents an attempt to combine the one-piece and the two-piece form by the use of slabs united by metal rods or

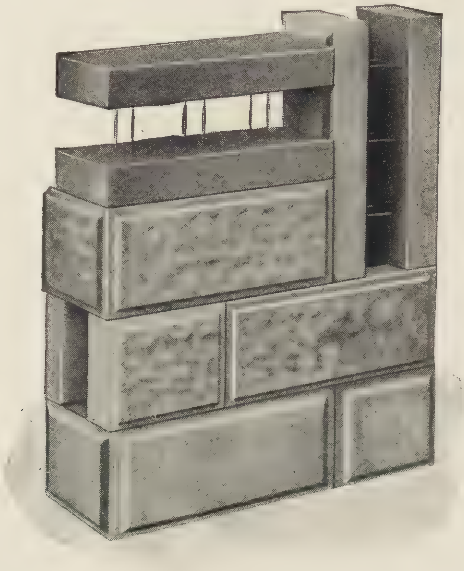

FIG. 5.—Blocks consisting of Two Slabs connected by Metal Ties.

ties, the ends of which are imbedded in the outer and inner slabs. The object is to secure a continuous air-space of uniform size throughout the wall. This form of block has been seriously criticised from an engineering standpoint, and it has been stated that the object sought is attained at the expense of correct construction. By its advocates the fact is cited that metal rods are extensively and satisfactorily employed in reinforced

concrete work; while its opponents answer that, in reinforced concrete, the iron or steel is protected from rust and corrosion by the concrete in which it is imbedded, while, in the type of blocks illustrated, the tie-rods are without such protection, and therefore subject to deterioration from atmospheric action, as well as to rust from the moisture penetrating the outer shell of the wall. However this may be, the fact remains that at least one house was built over twenty years ago from concrete slabs tied by metal rods, and is in a good state of preservation at the present day. While the form and method of fastening the rods vary slightly from that illustrated in Fig. 5, substantially the same principles are embodied in the blocks used in the house, which has two decades to its credit. It may be merely a coincidence, or it may be a fact worthy of note, that this house has been repeatedly struck by lightning. By some it is claimed that this is due to the attraction of the metal rods. It is, however, of greater importance to observe that the resultant damage has in each case been so slight that repairs were easily and quickly made.

In Fig. 6 are shown blocks of the standard two-piece type, while Fig. 7 illustrates more plainly the method of laying in the wall, the continuous horizontal air-space, and the method of bonding. Two-piece walls were brought out some four years ago with a view of overcoming some of the difficulties of manufacture attendant upon the making of the one-piece blocks, of enabling the operator to follow more closely the recognized standards of good concreting, of enabling the builder to adhere to the principles of the best engineering practice in wall-construction, and of affording a more thorough insulation than that secured by one-piece blocks. Care was also taken to avoid all of the objectionable features attendant upon efforts to construct two walls with an intervening air-space, and this could only be

accomplished by blocks of such shape that those forming the outer face should bond with those forming the inner surface

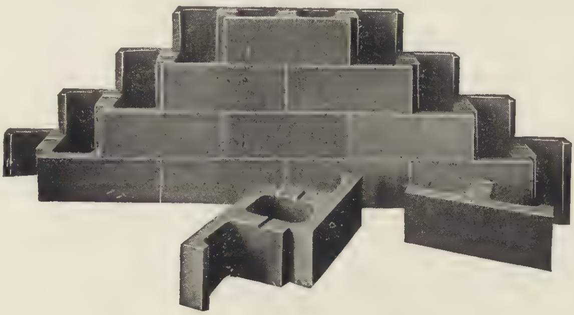

FIG. 6.—Two-piece Blocks and Wall.

by the overlapping of projections in alternate courses. The immediate and continued success of the two-piece system, and its adoption in many structures of such size and importance

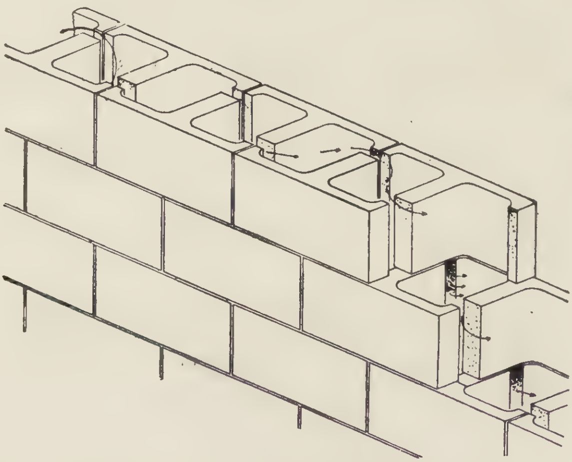

FIG. 7.—Diagram of Two-piece Wall, showing Air-space and Bond.

that it was scarcely hoped that concrete blocks would be adopted, proves that the best architects and engineers were quick to recog-

nize its points of superiority. The type of block shown in Fig. 6 is probably the earliest form of two-piece block to come into extensive commercial use, as the building shown in Fig. 8 is the earliest structure worthy of mention in which two-piece walls were used. It is a noticeable fact that, though the earliest, this type still maintains its supremacy, and is to-day regarded as the

FIG. 8.—Angelus Hotel, El Paso, Texas.

acme of perfection, because the lines of the block are correct from the engineer's and the architect's point of view. It will be noted that, while a modification of the T-shape, it possesses a distinct advantage in the short reinforcing arms at either end of the face-section. It has strength in its various parts in proportion to stresses which it is called upon to withstand, and not only breaks joints between courses, but breaks joints laterally

in every course, thus leaving no vertical joints extending through the wall, and giving the same result as established methods of bonding in brick and stone work by the alternate overlapping of long and short arms. It is in the manufacture of this block that one of its great advantages lies. As each block has but one face, interior cores are eliminated, and it becomes possible to make the blocks under direct and instantaneous pressure without the use of a tamper. This practice permits the use of as large a percentage of water as may be necessary to fulfill the requirements of standard engineering specifications for a medium or quaking mixture, and at the same time it allows the use of as large size aggregate as may be desired. Thus not only is a much more thorough crystallization secured in the initial set than is possible with a dry mixture, but far greater strength and density are obtained than can be possible in a sand and cement mixture. One of the most notable advantages of this block lies in the facility with which a continuous horizontal air-space is produced throughout the wall, as shown in Fig. 7, by leaving open the interior vertical joints. This is entirely practicable without loss of strength, owing to the indestructible bond in the wall. This horizontal air-space is valuable in relation to every phase of insulation, but particularly because of its prevention of the penetration of moisture by capillary attraction and the consequent insurance of a dry interior in damp weather.

Fig. 9 shows the adaptability of two-piece blocks to multiple air-space construction by so arranging the blocks that an interlocking bond is secured. The extension of the same principle to include a number of members greater than three may be utilized to build a wall of any desired thickness. Such walls are very serviceable for any heavy construction, and are especially designed to meet the requirements of cold-storage plants, ice-houses, or any buildings requiring unusual insulation.

Fig. 10 shows a one-piece block of a pattern radically different from those heretofore described. The idea of this block is to so dispose the webs and hollow spaces that each web will be backed by an air-chamber, and that no portion of the solid concrete will extend directly from the outer face of the wall to the inner side, the object sought being resistance to penetration of mois-

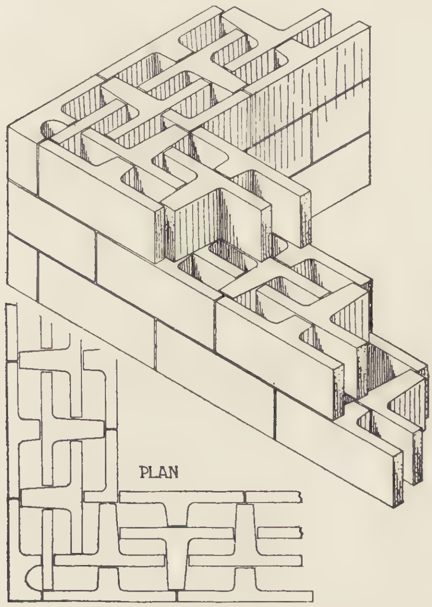

FIG. 9.—Interlocking Three-member Wall.

ture by rendering it impossible for capillary attraction to draw water to the interior of a building except by a route so circuitous as to be an impossible pathway. These blocks have, during the past two years, been extensively introduced, especially throughout the Mississippi Valley, where the humidity is great and the demand for dry walls imperative. They have accomplished the purpose for which they are designed in an admirable manner,

and, in every case where due attention was given to proportioning mixing and compacting, have given general satisfaction. A press was formerly employed in manufacturing blocks of this type; but as they must be made in an upright position, the form prohibiting their manufacture in either a face-up or a face-down machine, the press was discarded, and they are now generally made by tamping in molds of the "roll-over" style.

It is not claimed for this chapter that it describes in detail all of the points involved in any particular shape of block. It is manifestly aside from the scope of this work to give the minute

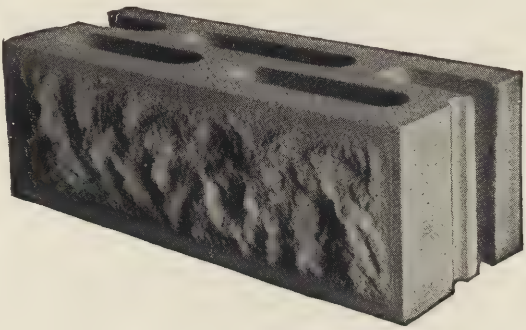

Fig. 10.—Block with Staggered Air-space.

details of the many variations in the shape of nearly all of the types mentioned. It has rather been the purpose to present some of the more patent advantages and disadvantages of the general types illustrated, which may be said to fairly cover the more decidedly novel features of the many styles of blocks on the market.

To one who follows the subject closely, the thought cannot fail to come that too much inventive genius is devoted to devising various shapes of concrete blocks. From week to week, and from month to month, the designs of different-shaped blocks have increased in number until they are as the sands of the sea-

shore,—no man can number them. If any good could possibly come to mankind from this waste of genius, it would be very far from the purpose of this work to criticise those who are devoting their time to the fruitless task. There is, however, in this multiplicity of designs no added usefulness developed, no novel features displayed, and no step taken which will aid the advancement of the industry. The sole idea of the present-day block-designers appears to be the avoidance, by the slightest change possible, of the rights of those who have preceded them. If the childish variations which are made were meritorious, it would be well. In general, it does the changers no injustice to say that their alterations are detrimental. Indeed, very many of them are never intended for commercial use, while others are so impracticable that any effort to use them in actual practice can only result in absolute failure. What the concrete-block industry needs is better workmen rather than more geniuses.

CHAPTER IX.

PROCESSES.

In considering the processes of concrete-block manufacture, it is necessary to consider only the methods used in compacting the mass, because the operations before and after this part of the process are, except as to the amount of water used and the size of aggregate, identical. It is, however, desirable to note that, while the subject-matter of this chapter has been the cause of unlimited contention, it is not more essential to successful work than the preliminary proportioning and mixing, or the final curing. While the nature of general concrete work and the necessities in connection with depositing the concrete in place admitted of but two methods of compacting the mass, namely, ramming or pouring, the altered conditions in a concrete-block factory have introduced the additional factor of pressing, and each of these three methods has again been divided, so that we have six different processes:

1. Hand-tamping.
2. Pneumatic tamping.
3. Pouring in iron molds.
4. Casting in sand.
5. Mechanical pressure, both hand and power.
6. Hydraulic pressure.

In hand-tamping the best possible results are obtained by light and frequent ramming of a dry mixture of sand or screenings and cement. The use of a dry mixture is necessary to cause the mass to compact under the blows of the tamper instead of squashing, or being thrown outside the area of contact, by the force of the blow. It is only in a dry mixture that the quick adhesion of particles obtains, which is necessary to prevent dislodgment of those portions already tamped by blows upon adjacent portions of the mass. For similar reasons, the use of a coarse aggregate is impracticable.

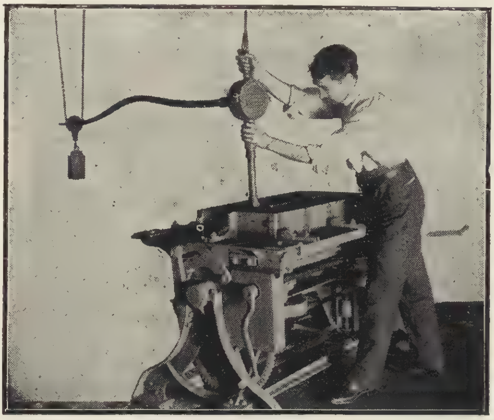

FIG. 11.—Pneumatic Tamper in Operation.

Successful block-making by hand-tamping is a matter of industry and endurance. To reduce the labor and secure uniformity in the product, pneumatic tampers similar to that shown in operation in Fig. 11 are now used in a considerable number of factories with good results. Their action is, of course, rapid and uniform, and the work much lighter.

The process of pouring in iron moulds was designed to secure greater strength by using a large percentage of water to over-

come the lack of crystallization in the initial set of a dry mixture. As the mass is reduced to a fluid state, it settles to place in the molds by its own weight and results in a very hard block. To this process there are three valid objections. The top and bottom of a block, considered according to its position in the mold, are not uniform, as the heavier particles gravitate toward the bottom. Owing to the time required for a very wet mixture to absorb, or throw off, enough of the water that the block may attain sufficient rigidity to prevent deformation when the support is removed from its side, the mold is in service several hours for each block manufactured, and therefore a very large number of molds must be provided to produce the output of a moderate-size factory. No satisfactory surface for fine work can be obtained by the simple act of pouring concrete into an iron mold, and it becomes necessary to produce a face by auxiliary treatment. This is accomplished in various ways. By one method the mold is arranged so that the face of the block will be uppermost and it is smoothed, and, while very wet, coated with screened marble-dust, giving a fine granular texture to the surface. By another method the blocks are chipped by hand while in a semi-plastic state, and thus an imitation of pitch-face stone-work is secured.

Casting in sand is not in very general use for ordinary block-making in this country, owing to the expense incident to this method of manufacturing. It has, however, been extensively used for the making of blocks for all portions of buildings in Havana, Cuba, and is largely used in the making of ornamental work in the United States. The process is on the same general lines of casting as followed by iron-molders, and results in blocks that are not only very hard and very durable, but that accurately follow the detail of the pattern and present a beautifully finished appearance.

The possibilities attendant upon the condensation of concrete blocks by mechanical pressure are of recent discovery. It is within the last three years that both hand- and power-presses have been devised for successfully producing high-grade blocks with a saving of labor which has brought the manufacturing cost below that of older processes. The principle upon which this development is based is that, by confining in a mold, properly vented for escape of air, a medium-wet mixture of coarse concrete, of which the larger-size aggregate may measure from $\frac{3}{4}''$ to $1''$ in its greatest diameter, and simultaneously applying to every part of the exposed area of the concrete an instantaneous pressure by power sufficient to thoroughly condense the mass, a more dense and homogeneous block can be secured than by any formerly mentioned process. The fact that blocks so made have withstood the most severe tensile, compressive, and fire tests proves the correctness of this theory. The fact that blocks so pressed have been used in several of the most important structures yet built of blocks is sufficient recommendation of its success from a practical view-point. In pressing blocks it is essential that voids be eliminated by adequate provision of means by which the air contained in the mass of loose concrete may escape. It is also essential that means be provided for determining that each block is uniformly pressed. This may be done either by suitable device for measuring pressure, or by adjusting the press to an arbitrary stop. In the latter case the concrete must be uniformly mixed, uniformly deposited, and the mold filled to a uniform height.

The application of hydraulic pressure to block-making is not of so recent origin as the application of mechanical pressure; but the former has not met with universal introduction, because, while the degree of compactness secured has ever commanded recognition, the time required in the manipulation of a hydraulic

press has been an obstacle easily overcome by use of mechanical pressure. Recently, however, large presses have been constructed in which a number of blocks may be pressed at one time; and, though cumbrous, this later development offsets to a degree the objectionable feature of the time lost in making a single hydraulic pressure.

CHAPTER X.

PLASTICITY.

THE question of normal consistency of concrete for block-manufacture has been too largely determined by prejudice instigated by manufacturers whose machines were adapted to but a single degree of plasticity. This is to be deplored, inasmuch as the value of those well-defined principles underlying good concrete construction is greater than the value of any particular machine, or any particular type of machines. These principles have gradually been deduced from results obtained from actual work under varying conditions during that period of years since cement assumed its place as an important factor in the industrial life of the nineteenth century. The best engineering talent of the great railways, and of our national government, has been directed toward the ascertainment of those practices which would result in concrete work of the greatest strength and durability; and for the almost unanimous decision reached, that a medium-wet mixture should be used whenever practicable, there must be a reason. It is to be found, in the first place, in the chemical action produced in the cement by the addition of a proper proportion of water. In common parlance, this chemical activity is described as setting, or crystallization. The exhaustive researches of Le Chatelier have not only established the fact that tricalcium silicate is the essential chemical element in the setting of Portland cement, but that crystallization only ensues

after sufficient water has been consumed to decompose this tricalcium silicate. In the second place, aside from any chemical question, the mere mechanical problem of coating the aggregate and filling the voids is sufficient ground for abandoning the use of an ultra-dry mixture.

What is ordinarily known as a dry mixture is of the consistency of damp earth. If a lump of dry concrete be compressed in the hand, it will not give off sufficient water to soil the hand, but it will instantly acquire sufficient rigidity to retain its shape. It is this latter quality which has brought dry concrete into such favor in connection with block work. The fact that it would instantly hold the position to which it was rammed by the tamper, and that the face-plates could forthwith be withdrawn from the block, has been so great a factor in facilitating the manufacture, and consequently in reducing the cost, of the product that those well-established scientific principles which make for quality have been sacrificed to speed and cheapness. In all frankness it must be said that the dire effects of the use of a mixture so dry as to cause weak blocks, liable to disintegration within a few years, is not wholly chargeable to the manufacturers of machines. They customarily recommend the use of a mixture as wet as practicable; but this passes the matter on to operators of whom too many, ignorant of the principles underlying the business in which they have engaged, interpret this instruction as a license for them to use the mixture which they can manipulate with the greatest ease.

It is, however, only in machines which make blocks by tamping that the ultra-dry mixture is available. The medium mixture is used in all machines operated by pressure, whether hand, mechanical power, or hydraulic. By a medium mixture is meant one containing so much moisture that it will quake, and water will flush to the surface when the mass is compressed. It is not

possible to specify an unvarying percentage of water without acquaintance with local materials. In general, it may be said that a broken-stone aggregate will require a larger percentage of water than would be needed in concrete made from sand and gravel aggregate. By the use of a medium-wet mixture a more thorough crystallization is secured in the initial set of the cement, and a better concrete is obtained by reason of more thorough coating of the aggregate and more complete filling of voids.

A wet mixture is used only in poured work, and involves the use of so much water as to reduce the concrete to a fluid mixture suitable for pouring, and requiring neither tamping nor pressure. From a chemical point of view, it is claimed that care must be exercised to avoid using so much water as to "drown" the cement, and, from a mechanical standpoint, voids will result through evaporation unless means be provided for the escape of superfluous water during induration. This is usually accomplished in plain work by the use of porous molds, while in ornamental work, by the process of casting in sand, the water which is not consumed by the internal chemical action of the cement readily finds its way into the sand.

CHAPTER XI.

FACING.

The difficulty of obtaining, by molding concrete of usual texture, a suitable appearance for the better grade of exposed surfaces, has led to efforts along various lines looking toward the attainment of more pleasing surfaces. Owing to the board-forms ordinarily used in monolithic construction being taken down as soon as the concrete will retain its shape without support, the practice has been well-nigh universal in that class of construction to plaster a rich mixture on the coarse concrete immediately after removing the boards. It has been found that adhesion can only be secured by roughening the surface of the set concrete with a wire brush, and thoroughly wetting this roughened surface before applying the facing. Even with these precautions, cases are frequent in which the contraction of the richer mixture during the setting of its cement has caused cracks and resulted in separation between layers. Another objection to this method lies in the troweling incident to finishing, which draws the cement to the surface and results in hair- or crazing-cracks.

As it was not prudent to risk, in blocks for the construction of buildings, such dangers as have been mentioned, it was not, in the earlier stages of the manufacture of concrete blocks, thought feasible to face the blocks with a mixture differing from the body of the block. Later developments have shown that there

are other methods of facing, applicable to block-manufacture, which eliminate the difficulties attendant upon the method of facing and troweling after manufacture. The mixtures commonly used for facing vary from 1:1 to 1:3, while the backing or body of the block varies from 1:4 to 1:3:4. In the case of blocks tamped in an upright position, one side of the mold must needs form the face; and the only way of applying a half-inch face of the finer material is by the insertion of a partition to separate it from the main body of concrete. It is evident that this leaves a distinct line of cleavage between the two sections, and does not insure absolute permanency. It is becoming quite common to make blocks face down. There are now many machines on the market, adapted to the latter method of facing, which contemplate the introduction of the face-matter first, and its thorough tamping against the face-plate before the coarser concrete is deposited in the mold. In this way the partition is eliminated and the line of cleavage less marked. In the manufacture of two-piece blocks under pressure, the face-matter is applied in the top of the mold before the block is pressed; and thus, upon subjection to heavy pressure, it becomes firmly imbedded into the underlying coarse mass, and no distinct line of cleavage remains.

It has been generally supposed that the color of cement had a very potent influence on the color of the face. While there is an element of truth in this belief, it is a fact that the color of aggregate and the purity of water are factors more worthy of consideration. In many block-factories, cements of a particular color—usually white—have been imported from France or other European countries, when a smaller increase in cost would have obtained an aggregate giving, with the native Portland cements, more nearly the result sought. For approximately white facing, it is evident that white sand or stone screen-

ings should be used. Irrespective of color, however, the selection and preparation of sand for face-matter is of the greatest importance. It should be fine, sharp, of a hard and close texture, and scrupulously clean. It should be screened immediately before mixing, not only to remove any large particles, but to loosen it up as much as possible, so that the mixing may be more thoroughly accomplished. Owing to the tendency to stick to plates, face-matter is usually mixed dryer than the body of the block, and, as it is always a rich mixture, there is a slight tendency to roll up into balls. It is, therefore, necessary to again screen the mixture immediately before it is used.

For colored work the best practice demands the use of screenings from crushed stone of the desired color. Indeed, this is the only truly correct and practicable manner of obtaining strong and durable colors without sacrificing the strength of the block. There are but few plants in which this method has been extensively used, but it is, nevertheless, the method which must survive.

There are several firms, now manufacturing various colors for block work, using iron pigments as a base. Of course it is understood that vegetable colors, or colors containing oils, greases, or acids, cannot safely be used in concrete work. Many writers, have undertaken to give directions for the use of ultramarine, ochre, lampblack, iron oxide, and a great variety of other coloring matters. The facts in the case show two things: First, that all colors produced by such artificial means are liable to fade with time; second, that the use of such adulterants in quantity adequate to produce the desired color, with sufficient strength to prevent fading for a reasonable time, weakens the concrete. Generally speaking, it is probably safe to say that an unfading color in concrete blocks can only be produced by use of an aggregate of the required color.

In facing blocks the chief end sought, aside from appearance,

is to obtain a surface approximately water-tight. The fact that only fine sand is used decreases the size of voids to such an extent that, by the use of a large proportion of cement, the face (if mixed reasonably wet and properly compacted) may be made nearly impermeable without the use of any chemical adulterant. There are, however, a number of compounds on the market, for use in face-matter, calculated to produce a perfectly waterproof surface. In absence of information as to their ingredients, it is manifestly impossible to express an opinion either as to their permanence or their ultimate effect upon the cement.

The form of face is a matter of the particular plates used in the manufacture of blocks, being, in the case of upright one-piece blocks, one side of the mold, in the case of face-down blocks the bottom of the mold, and in the case of two-piece blocks the pressing-plate. In supplying these plates, it has been the usual custom to regard pitch-face as a standard design. That it is an imperfect imitation of the cheapest class of stone-work, that it lacks the boldness and variety of outline found in the original, and that it robs cement-work of its own intrinsic merit, does not deter the block-maker from using a face which will not show the imperfection of his work or the loose texture of his blocks, and he inflicts upon a gullible public a design suitable only for basement and stable construction. Equally culpable and inartistic is he who, by a repetition of designs produced from the same face-plates, destroys the decorative possibilities of concrete architecture by a sucession of monotonous ornamentation. The manufacturer of machines, the block-maker, and the architect of concrete-block structures will alike do well to consider that the decorative features of concrete blocks lie not less in plain and imposing walls than in contrasting ornamentation. They may also remember that the value of ornamentation is enhanced by beautiful walls of blocks that are plain, or by blocks

that are beveled to emphasize mortar-joints, after the manner of the rusticated exteriors of the Italian renaissance, with which tool-face blocks may be suitably interpolated. Such architecture will carry concrete blocks into structures where they could never go by the prevalent use of a dull, plastic-like imitation of hewn stone, or a motley conglomeration of inartistic ornamentation.

CHAPTER XII.

ORNAMENTATION.

As suggested in the previous chapter, ornamentation should, in concrete-block buildings, be a contrasting decorative feature. It is therefore evident that in quantity and size it constitutes, in truly artistic construction, but a small proportion of the building; and it may be fairly assumed that its production warrants a manufacturing cost which would be beyond reason for the main portion of the walls. This statement is further emphasized by the fact that such ornamentation is successfully replacing a good quality of hand-cut natural stone, the cost of which is far beyond that of ornamental cement-work produced by any process.

In considering the methods by which ornamentation may be produced we may, for reasons stated in Chapter XI, pass those designs furnished with a number of machines, whose manufacturers have modified the egg-and-dart and a few other standard ornamental features by eliminating the undercut, and who furnish iron plates cast from such patterns.

Fig. 12 shows ornamental work manufactured for the Chicago Drainage-canal Power-house, near Lockport, Ill. The process used in producing this work involved the casting of plaster molds from patterns. The cement was poured into these molds, and, owing to the undercut, the molds were broken after the cement had hardened. Of course, where there is no undercut the molds can be made in sections and removed without breakage.

One very large company of ornamental workers employs sectional wooden molds almost exclusively. These must be thoroughly shellacked to prevent warping and cracking.

Glue molds have been extensively used in the finer lines of ornamental cement-work. A well-molded glue negative may be used about twenty times, as its elasticity permits removal from work having a considerable undercut.

FIG. 12.—Ornamental Work for Chicago Drainage-canal Power-house.

Casting in sand seems to be the easiest and, all things considered, the most inexpensive method of producing thoroughly satisfactory ornamental work. As it requires merely a wooden pattern, iron-molders' sand, and wet concrete, it is evident that a high degree of skill is not essential to perfect work. The only item of great expense is the pattern, and this may often be secured

in natural stone or some other material, if of a design not obtainable in wood, without the services of a pattern-maker.

It is but fair, to that one who is about to embark in the business of manufacturing and selling concrete blocks, to state that he should not undertake elaborate ornamental work without long experience in the more easy departments of concrete manufacture. The manufacture of ornamental work is distinctly a separate branch of the cement industry, and one requiring great skill. The ease with which cement assumes any desired form, and the beautiful effects produced by the skillful operator, lead the novice to tread on most dangerous ground. It is one thing to make an ornament, and quite another thing to produce one that will stand the test of time. The sharp arrises, the fine lines, and the intricate designs of desirable ornamentation require a degree of familiarity with the action of cement, both in molding and in exposure to atmospheric influences, which is too often gained by the loss of a customer's goodwill. Above all things, the common practice of employing chemicals for accelerating the set of cement, in the production of ornamental designs, is to be deprecated as irreparably harming the business of the future.

CHAPTER XIII.

CURING.

There can be no greater error in block-making than to consider the process of manufacture complete when a block is taken from the mold. It is in the application of scientific methods to the subsequent induration of the block that this style of construction possesses a marked advantage over monolithic concrete construction. It is in the adaptability of concrete blocks to thorough curing before laying that they are capable of acquiring that degree of strength and durability which is ultimately destined to place them in the first rank as a building material. It must not, however, be supposed that the mere setting away to cure, or allowing to dry, constitutes what is rightly embraced in the comprehensive process termed curing. It rather involves a most careful application, during a series of days, of scientific methods calculated to give quality to the product, and it is to a neglect of such methods that most failures in block-making are attributable.

As is well known, cement is the bonding element of concrete, and its value in that regard lies wholly in its hydraulicity. As mentioned in a previous chapter, crystallization is the result of hydration, and thorough crystallization is only effected by the use of a considerable quantity of water. It must be still further considered that crystallization is by no means an instan-

taneous process; that only what is commonly termed the initial set is secured by the admixture to the cement and aggregate of the amount of water most commonly used in molding blocks; and that reliance must be had upon subsequent addition of moisture to secure that later crystallization without which blocks are worthless for practical purposes.

Maintenance of uniform conditions is the keynote to successful curing. It is absolutely essential that blocks shall not, during the period of curing, be exposed to the sun. The reason for this becomes apparent if a freshly-made block, thoroughly saturated with water, be exposed for a few hours to the direct rays of the sun. It will be noted that one side becomes very dry while the other remains moist; and the exposed side will show a baked appearance, and, by the rapidity of contraction, develop checks and shrinkage-cracks, while serious structural cracks are liable to result in the interior of the block, owing to the variance in rate of contraction between the front and back. It may here be noted that a large percentage of cracks, both structural and surface, are caused by rushing green blocks into a wall. Many operators have, in their earlier experience, made the mistake of placing in a wall blocks only three or four days old; and the results, especially if the wall be exposed to the sun, have fully justified a sweeping condemnation of such practice. It will ever be a source of mortification to the block-maker if he allows the insistence of a builder, who is anxious for blocks on a certain day, to lead him to deliver partially cured blocks to be used above ground.

The main element in curing, under methods now commonly in use, is water, and it should be applied at such intervals and in such manner that the condition of moisture will at all times be uniform. This may be secured by sprinkling the blocks thoroughly three or four times a day. The amount of water

and the frequency with which it should be applied are dependent to a great extent upon weather conditions. It is evident that in cold weather, or in a humid atmosphere, sprinkling may occur at less frequent intervals than would be necessary in a dry climate or in very hot weather. Sprinkling should begin as soon as the blocks have attained sufficient rigidity that a fine spray will not deface the surface. If a dry mixture has been used, it is evident that a larger amount of water will be consumed than will be the case where blocks have been made of a medium or a wet mixture. In the former case, blocks should be kept thoroughly moist for at least twenty days, while in the latter case ten days will suffice. A rule which should not be violated under any circumstances is that blocks of dry mixture require minimum curing of fifteen days, and blocks of medium mixture require minimum curing of seven days. The sprinkling should be so thorough that no portion of any block will turn white; and especial attention should be given to any ornamental designs, as well as to corners, which usually dry faster than the main surface. To maintain uniformity of moisture, it will be found useful to protect the blocks with hay, excelsior, burlap, or any substance which will serve to retain moisture. By first thoroughly wetting a pile of blocks, covering in this manner, and then keeping the covering matter thoroughly wet, the loss of moisture otherwise obtaining may be prevented, and the blocks be constantly surrounded by uniformly moist air.

A circulation of air is desirable as between and among the blocks; and not only for this reason, but also to prevent discoloration, blocks should not come in contact with one another, but tiers should be arranged so that a slight air-space will intervene, and layers should be separated by laths laid between. In this connection it may be noted that uniform color can only be obtained by uniform curing. The influence of curing upon color is a

matter which has not been given so serious consideration as it

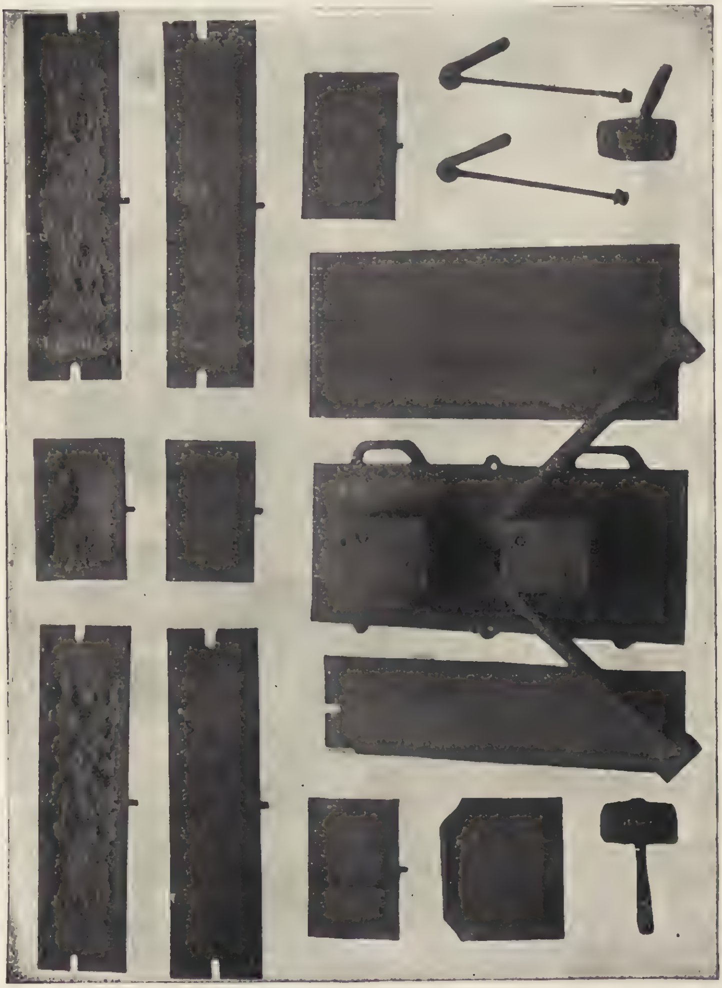

FIG. 13.—Full Set of Molds and Accessories forming a Simple Equipment of the Roll-over Type.

deserves, for it is a most essential factor in securing that uniformity of appearance so much desired.

Steam-curing of blocks is a matter in which considerable interest is manifested at this time. It is of course well understood that placing blocks in live steam will effect an apparently thorough cure in an incredibly short time; but the experiments along this line have been so few, and the statements of actual results observed during any considerable period of time are so limited, that the expression of decided views on the subject is not yet justified. It is, however, interesting to note that, in the construction of a very large public building in the State of New York, the local company which is manufacturing the blocks is also the owner of a sand-lime brick-plant, and has, in the steam-cylinder of the latter plant, cured blocks so effectively that when forty-eight hours old they have been placed in the wall beside blocks cured for the customary time by usual methods. It is the present belief that the best results in steam-curing are obtained by exposing the blocks in thoroughly moist air for twenty-four hours before subjecting them to steam, thus following standard practice for accelerated tests of cement briquettes.

Curing in freezing weather is difficult, but not impossible. The blocks must be kept from freezing for the first four or five days to avoid expansion-cracks caused by swelling from freezing. At the end of that time sufficient firmness should have been attained to withstand the tendency to expansion; and in that case no damage will result, as freezing only suspends crystallization, and a subsequent rise in temperature causes a resumption of the chemical process.

CHAPTER XIV.

MACHINES.

In considering machines and molds for the manufacture of concrete blocks it will be well to divide them into three groups and consider them in the following order:

1. Machines and molds for manufacturing blocks by tamping a dry mixture, using a comparatively fine aggregate.
2. Machines for compressing in molds, without tamping, a medium-wet mixture, using an aggregate graded from fine to coarse.
3. Molds for forming blocks by pouring a wet mixture.

It must be understood by the reader that this classification is to a certain extent arbitrary, and that there are certain points where the various classes overlap. It must also be understood that the list of machines illustrated or described is not submitted as complete. The limitations of this work by no means permit of a description of each machine on the market, but it has been the intention to select such machines as exemplify certain principles of manufacture; and the same principles are in many cases embodied, with slight mechanical changes, in a large number of various makes. Neither is it claimed that the description sets forth all particulars relative to the operation of any particular style. These particulars are readily ascertainable from manufacturers' catalogues, and it is very far from the purpose

to make this work in any sense a compilation of catalogue literature. It is rather the purpose to present some of the more marked peculiarities of the various types, and to mention some of their more patent points of relative merit and demerit.

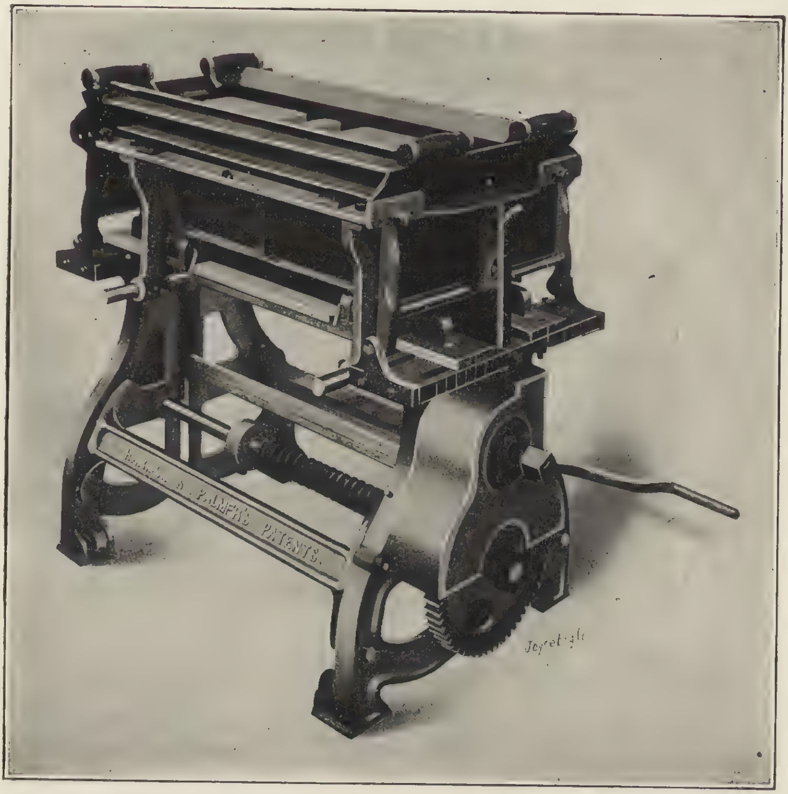

FIG. 14.—Upright Machine with Drop Cores.

The objects of a concrete-block mold or machine are six:

1. Means for enclosing the mass during formation into desired shape and size.
2. Means for properly and quickly compacting the mass.

3. Means for giving desired variation to exposed surfaces.
4. Means for making a face of texture differing from the body of the block.
5. Means for rapid discharge of the product.
6. Means for preventing injury to the block while green.

All of the six factors mentioned may fairly be said to be entitled to consideration in every machine, and the various machines show the result of attention directed especially to one or another of them.

In Fig. 13 is shown a full set of cores, plates, and the like, comprising a medium-price outfit of the roll-over type. In operating this outfit the plate to which the cores are attached is set on a level surface or working-table of convenient height; the plates comprising the sides and ends are selected according to the particular design desired for the surface of the block and are clamped in place. The mold is then partly filled and the mixture tamped, this filling and tamping being repeated until the mold is heaped slightly above the sides. The mixture in the mold is then leveled with a straight-edge, and a board somewhat larger than the block put on top. The whole apparatus is then turned over so that the mold rests on the board. The iron plate is now lifted straight up, withdrawing the cores with it; the sides of the mold are unclamped and removed, and the block is set away to cure on the board.

In Fig. 14 is shown an upright machine upon a metal stand, being the latest model of one of the first manufacturers of block machines. The especial feature of this machine is the dropping of the cores out of the block after it has been tamped. Simultaneously with the dropping of cores the sides are opened, as shown in Fig. 15, and the block removed on an iron pallet of the shape and size of the block itself, and having openings corresponding to the cores and hollow spaces. This type of machine

has been very closely imitated by many manufacturers who have entered the field in later years. The variations which they have made from the original have been calculated to secure greater facility of operation, or to attain greater efficiency in some one

FIG. 15.—Upright Machine Releasing-block.

of the essential points mentioned in opening this chapter. It appears, however, that the recent improvements embodied in this machine are well calculated to enable it to maintain its position of supremacy among the upright machines. Despite the efforts of its imitators to belittle its efficiency, it must be acknowl-

edged that its product is uniformly excellent, and that many worthy buildings stand to its credit.

FIG. 16.—Moving the Mold rather than the Block.

In the mold illustrated in Fig. 16 the point of preserving the block from deformation while green has been emphasized by

leaving the block on the ground where made and removing the mold from the block, thus relieving the block from any jar in handling until it has become somewhat hard.

Fig. 17 shows a machine in which the characteristic feature

Fig. 17.—Face-down Machine.

is facility of facing. There are many machines now manufactured embodying the same general principle shown in the illustration. They are commonly termed face-down machines, and use the plate forming the outer surface of the block as the

bottom of the mold, on which the fine facing matter, varying from 1:1 to 1:3 mixture of cement and fine sand, granite screenings or marble dust, is deposited and thoroughly tamped, after which the leaner mixture comprised in the body of the block is deposited and tamped in the usual manner, except that the cores, which it will be noted enter and withdraw laterally, are not inserted until the lower half of the block has been tamped to place. In most machines of this type the mold is so arranged that, when the block is ready for delivery, the mold may be turned to an upright position and the block released either on a wooden pallet or on an iron bottom-plate in the manner described in connection with the upright machines.

In Fig. 18 is shown a machine which was originally of the upright type, on which the manufacturers later arranged a device for tilting to an angle of 45° to admit of depositing face-matter without the use of a partition, and which, by still later improvement of the tilting device, has been brought into direct competition with face-down machines by the latest model, as shown in the illustration, which still preserves all the advantages of the upright type. The mechanical feature of this machine which claims attention is the raising and lowering of the bed-plate upon stationary cores, and the engaging of side and end plates by a frame which throws the mold into position for refilling as the bed-plate drops into position.

In Fig. 19 is shown a mechanical press for manufacturing two-piece blocks from a medium-wet mixture in which a coarse aggregate is employed. As it is the perfection of this machine which has brought two-piece blocks into the extensive use which they now enjoy, and as the method of operation is in every respect at variance from the machines already described, it may be interesting to consider in some detail the process of making pressed blocks. It will be noted that the pressure is applied by means

of upright hand-levers, which, by lowering either to the right or to the left, bring into action an arrangement of compound toggles which exert upon the movable bed of the press a pressure

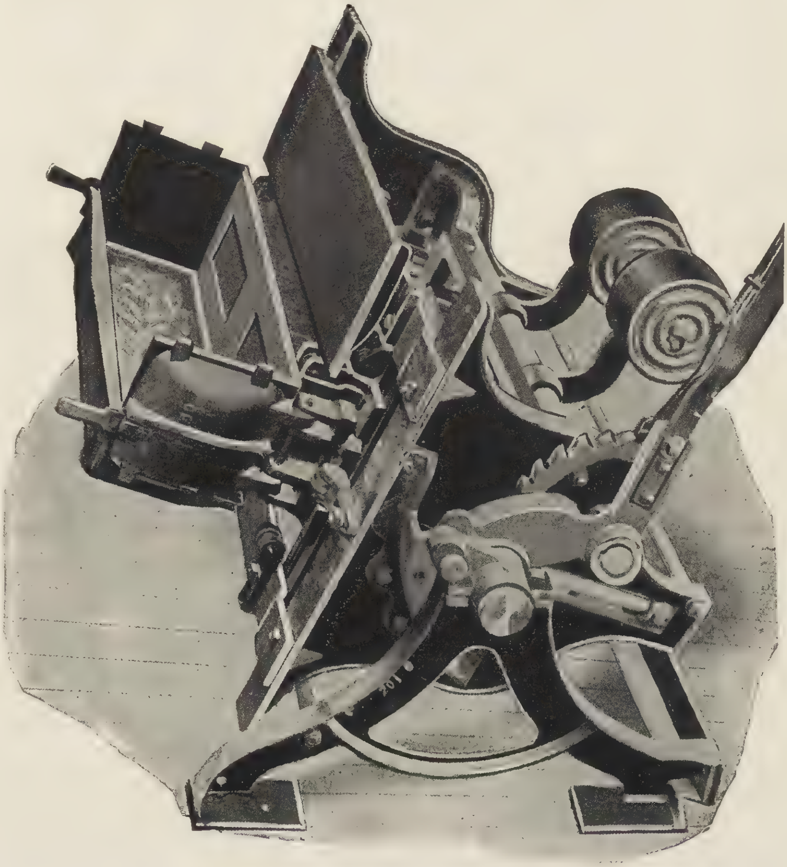

FIG. 18.—Combination Upright and Face-down Machine.

of 60,000 pounds. The molds are filled at their respective ends of the track, the medium-wet mixture of one part cement, three of sand, and four of gravel or broken stone being shoveled into the mold and raked off level. If it is desired that the face be

of fine texture, a gauge is used at this stage of the process, raking from the top of the mold a quarter or half inch of the coarse mixture, and a half-shovelful of fine face-matter, previously screened to avoid lumps, is applied. The pressing-plate of the particular design required is then put in place on top of the mold, and the mold, which is hung on trolleys having grooved wheels fitting the track, is then run into the press and the pres-

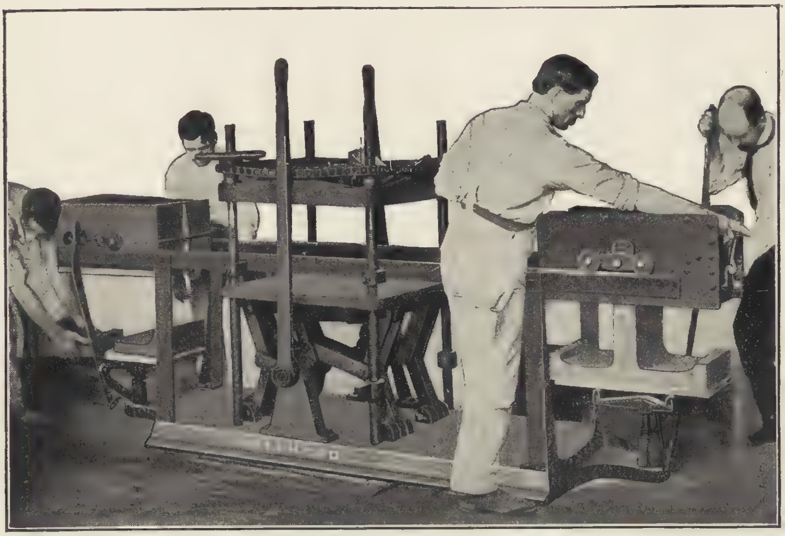

FIG. 19.—Mechanical Press making Two-piece Blocks.

sure made. From three to four seconds is required in this operation. As the pressure is relieved, the mold is withdrawn and two hooks thrown over the pressing-plate to hold it in place, while the mold is inverted and run to the end of the track. The releasing-stand, which is shown below the mold in the illustration, is then raised to engage the pressing-plate, the hooks loosened, and the block lowered (face down), resting on the plate by which it was pressed. The process is very rapid, expert men pro-

ducing unfaced blocks in twenty seconds and faced blocks in thirty. The making of corner, jamb, and other special blocks requires somewhat more time. Corner returns are faced by tilting the mold to admit the face-matter on the return, and the pressure on the return is given by an ingenious interior bevel which crowds the mass endwise. It should be especially noted that this machine is peculiarly adapted for manufacturing two-piece blocks, as it exerts the pressure directly on the face of the block; also that two-piece blocks are peculiarly adapted for manufacture in this machine, as they have no interior cores, and can therefore be released from the mold face down. It should be stated that the molds are provided with numerous vent-holes, which permit the escape of air when pressure is applied and admit air while releasing, thus obviating the creation of a vacuum behind the block. A number of different castings which are commonly termed cores, but are not interior cores, are provided for making many different shapes and sizes of blocks, the range in width extending from the thinnest partition to a seventeen-inch wall, all being made in the same mold by adjustable cores and fillers.

The poured system admits of the use of a variety of different materials in the molds. The fact that compression is eliminated, and that the block becomes compact by the mere settlement of the fluid mixture, makes it unnecessary for the molds to resist any severe strain. For this reason, and because of its ability to take up the superfluous moisture in the mixture, sand is well adapted for such molds; and the process of casting in sand, as described in a previous chapter, has given rather better results than has the use of any other kind of mold. Wooden molds may be used, providing the wood be thoroughly waterproofed to prevent warping. Some two or three years ago a system of sheet-iron molds was placed on the market for making blocks

by the poured process. The molds are well adapted to the purpose, and have been installed in a considerable number of factories; but the fact that the natural gravitation of heavier portions of the mass to the bottom causes lack of uniformity throughout the block, and the difficulty of producing a satisfactory face, have served as obstacles, while the long time which the molds are retained in service before blocks can be removed, and the consequent large number of molds required for producing any considerable output of product, have greatly hindered the popularization of these molds.

CHAPTER XV.

PLANT ARRANGEMENT.

In the location, designing, and equipping of a plant the first requisite is ample ground-space, which should be located close to market. The plant should be within a reasonable hauling distance of that section in which it is anticipated that the majority of buildings of block construction will be located. One is inclined to feel that the essential thing in choosing a location is to get near the sources of supply of the raw materials, and hence make the mistake of locating a plant at a gravel-bank, or near a stream from which sand and gravel may be procured, overlooking the long haul entailed on the finished product. Unlike most contract work, it will be found much cheaper to haul the raw materials for block-manufacture than to haul the finished product. Great care must be exercised in the transportation of blocks from the factory to the building-site in order to prevent breakage and defacement. It must be remembered that the tiniest chip from the corner of a block often means to a conscientious operator, and not less to one who cares for future business, a total loss of the block. Hence a long haul on raw materials and a short haul on blocks is preferable to a short haul on the former and a long haul on the latter. If possible to secure trackage it is a great advantage, both as to receiving cement and such special

character of aggregate as may occasionally be necessary, and as to shipping blocks to outside points in contiguous territory.

In caring for freshly-made blocks it is necessary, except under processes leaving the blocks on the ground, that they should be racked. In small plants, racks for this purpose may be conveniently arranged by making for the ends and center of the rack a frame of 2″×6″ lumber and placing thereon 2″×4″

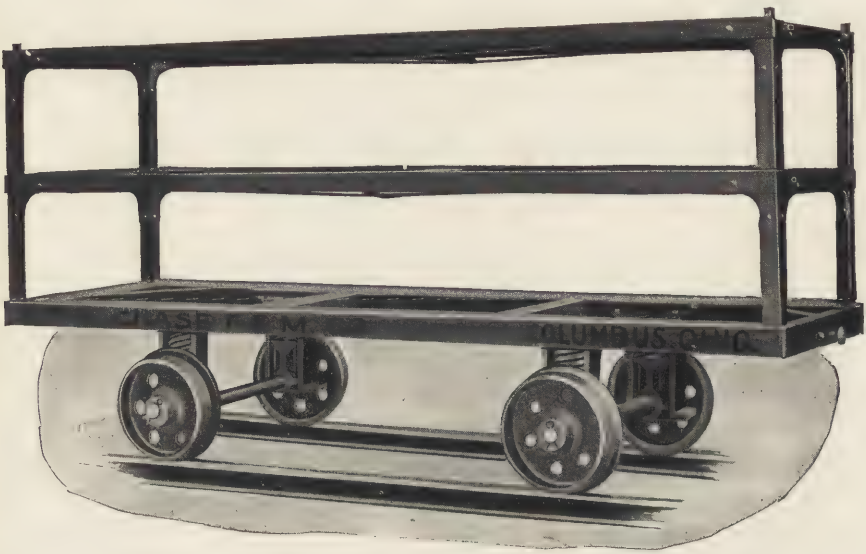

FIG. 20.—Car Suitable for Concrete Blocks.

stringers. The latter should not be nailed, but should be put in place as required, so that the off-bearers may have ample room for setting blocks on the stringers, and, as each tier of blocks is in place, the stringers for the next higher tier are put on the rack. For large factories, however, it is much better to provide cars for the product. In Fig. 20 a convenient type is shown. These may be obtained in various sizes suited to the particular type of blocks manufactured, or trucks may be purchased and

the cars built up of rough lumber, according to individual requirements. Tracks may be constructed of hard wood or of light T-rail, and should run from the machine to the curing-yard. It is a frequent practice to have considerable trackage in the shed adjoining the manufacturing-room, and to keep the blocks on the cars for several days before exposing them in the open curing-

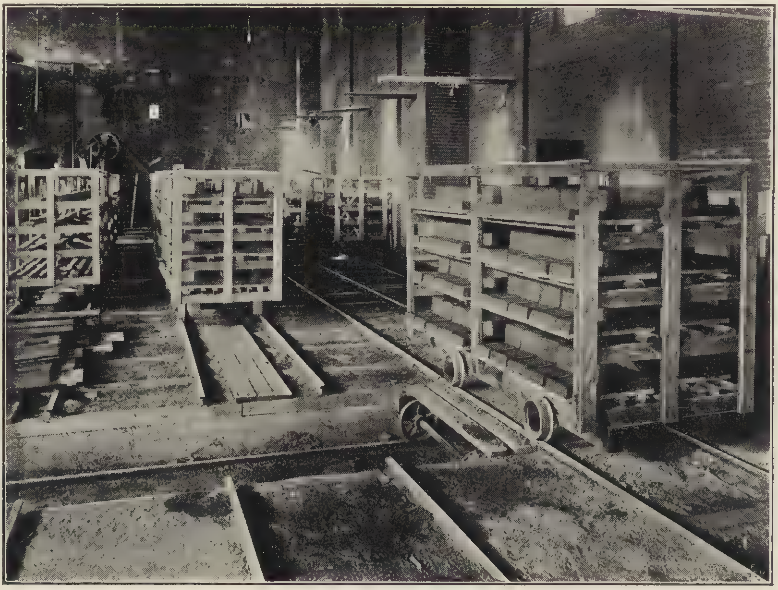

FIG. 21.—System of Cars and Tracks.

yard. In that case it becomes necessary to have a transfer-car for switching the regular cars from one track to another, consisting merely of a wheeled truck on a sunken track running at a right angle to the surface tracks. In Fig. 21 such a transfer-track is shown in the foreground. The cars shown in this illustration consist of wood frames built upon iron trucks. In this system of tracks, second-hand street-car rails were utilized. The

cars should sit very close to the machine while blocks are being manufactured, as an enormous amount of time is usually consumed in off-bearing owing to lack of proper convenience of cars or racks.

Doubtless the most convenient and economical arrangement for handling materials is, where circumstances permit, to have overhead sand- and gravel-bins discharging into the mixer, with the mixer elevated so that it will discharge on a platform of such height that the concrete may be readily raked into the mold. If, however, the contour of the ground renders such an arrangement impracticable, the same result may be obtained by the use of inclined belt-conveyors, which will be found the most satisfactory means for elevating and transporting concrete.

Of course either one of the elaborate arrangements mentioned in the last paragraph will not be installed in the small plant, but it is not of less importance for the smallest operator to carefully arrange his plant with a view of securing the greatest compactness and convenience. The bins should be close to the mixing-platform, and the mixing-platform close to one side of the machine, with racks readily accessible on the other side.

There are now few places where sufficient water-pressure to use a hose is not obtainable, and the application of water from a hose-nozzle is far preferable and more uniform than any other method. In the large yards it is customary to save labor by running a water-pipe around the curing-yard, having automatic lawn-sprinklers at intervals for wetting stacks of blocks.

The curing-yard is an important consideration, and must be comparatively large. It should be protected by a roof under which the blocks may remain until curing is nearly, if not quite, completed. In winter it will become necessary to enclose the sides, and this may be cheaply done with blocks. If desired, these blocks may be laid in lime-mortar, and taken down in the spring

for use in other construction. During the past winter one railroad company successfully operated on this plan, heating the temporary building by means of a large cannon-stove in either end and placing the machine midway, with blocks stacked at the ends.

CHAPTER XVI.

PLANT EMPLOYEES.

One of the most important factors in the success of a concrete-block plant is a foreman of intelligence, experience, and character. The oft-repeated statement of manufacturers of block machines, that the commonest kind of common labor can produce the best concrete blocks, is, to use the mildest language possible, misleading. It is to belief in this statement that a considerable number of block-makers might justly charge their failure to introduce blocks into their community, as well as their pecuniary loss. It is to the result of this erroneous advice that manufacturers may charge the failure of their salesmen to place machines in many towns adjacent to those where failures have occurred. The foreman of a concrete-block factory must possess, in a marked degree, those qualities of sterling character which make one a handler of men: he must have the capacity to systematize their duties and to accomplish results, and in addition to this ability he must know the nature, uses, and limitations of cement; and he must be especially versed in the theory and practice of mixtures, proportioning, aggregates, voids, and general concreting. He must so thoroughly understand the particular machine in use and the materials locally available that he will obtain the maximum of quality in his product under all conditions. He must know something of building construc-

tion and architecture, and must be able to take a set of working drawings and therefrom manufacture each block to fit its appointed place. He must be a judge of the capacity of a block to withstand the strain placed upon it, and be able to determine what, if any, reinforcement may be necessary to afford a requisite factor of safety. With such a foreman, a block plant cannot fail.

The mold-maker, who in smaller plants may be the foreman, must be able to manufacture from lumber, with or without a lining of galvanized iron, molds for such special members in building construction as are beyond the dimension capacity of the machine in use, and for such special shapes of blocks as may be required to suit the plans of the architect, and for which provision has not been made in the adjustability of the block machine. In the latter case, it is often unnecessary to construct an entire mold, but the regular mold may be used by the insertion of fillers. It must be understood that, however thoroughly the designer of a block machine may anticipate the many special shapes and sizes incident to all kinds of construction, it is impossible for him to foresee all the various modifications that may be introduced by individual architects unfamiliar with block construction; and the up-to-date block factory must be able to earn the approval of architects by building to their specifications rather than requiring their specifications to fit an arbitrary size or design of blocks. It is rarely understood by block-makers how easy this accomplishment is in the hands of an intelligent mold-maker, nor how small the additional expense. It is important, when molds are not lined with galvanized iron, that the interior be not merely surfaced, but that exceeding smoothness and protection from warping be secured by repeatedly alternating sand-papering with coats of shellac.

In a thoroughly equipped factory which aims to supply the

demands of the public in both plain and ornamental work, a capable modeler is a valuable employee. In one factory recently visited, the ability of the modeler and mold-maker were of so high an order that it was impossible for a customer to suggest any requirement in cement-work which could not be properly supplied without recourse to outside assistance. That is the ideal condition which will be approached to a greater or less degree, according to the extent of the manager's appreciation of the importance of really meeting the public need.

As to the common labor employed in a concrete-block factory, the position of many writers, that an inferior class of foreign labor is economical, is not well taken. In observing the operation of plants in which the major portion of the labor is intrusted to the hands of indifferent and incapable workmen, and in observing the operations of other plants in which the laborers are keen, energetic, and careful, and in inspecting the blocks turned out by each and the buildings erected therefrom, note has been taken of the ultimate bankruptcy of the one and of the increasing financial success of the other. There is, perhaps, no class of manufacturered articles in which the personal equation, the integrity and knowledge of the man who does the work, is more important than in concrete blocks; and it is impossible, by the purchase of the best and most expensive machinery or by the most rigid and competent superintendence, to eliminate this factor.

It is not expedient to disregard how or by whom the blocks are laid in the wall. The best blocks, when carelessly laid, produce but a poor and ill-appearing wall. A man who knew block-construction most thoroughly tersely remarked, in inspecting an especially fine wall, "Your mason knows his business." There is food for reflection in that observation. In many places the brick- and stone-masons appear to be antagonistic to block-

construction. This should not be, and the condition is very often caused by the attitude of the block-maker. As either brick- or stone-masons can satisfactorily lay the blocks, the matter should, if the place of operation be unionized, be frankly submitted to the trades council for their decision as to who shall lay the blocks. Their decision should be accepted by all parties concerned, and, if that decision be recognized as authoritative, harmony, goodwill, and good work will follow.

CHAPTER XVII.

VOIDS.

Eliminating from the discussion of voids considerations purely technical, it may be said that voids in concrete blocks are the result:

1. Of improper gradation of aggregate.
2. Of careless or insufficient mixing.
3. Of inadequate matrix.
4. Of lack of proper condensation.

It is scarcely necessary to state that, to every conscientious block-maker and to every proprietor of a concrete-block factory who desires to maintain and increase his patronage, a study of the causes of voids, and of those methods by which they may be eliminated, is of the greatest importance. He would indeed be a novice in the industry who failed to perceive that a porous block is a weak block; but the experienced manufacturer often makes the mistake of supposing that in a fine aggregate there is less porosity than in a coarse one, merely because the individual voids are smaller, and hence not so apparent to the eye. As a matter of fact, there is no appreciable difference in the percentage of voids in a uniform gravel and in a uniform sand, and it is therefore apparent that density in any marked degree is only obtained by such relative proportions as cause the larger voids in the coarse aggregate to become filled with the grains of the smaller.

The theory of correct mixtures and the methods of correct proportioning have received treatment in the chapter devoted to Proportioning, and it is necessary to add only that an observance of the methods there prescribed will be found the most facile means for the elimination of voids.

It is also to insufficient mixing, or to unintelligent mixing, that the cause of porosity may often be traced. Of this sufficient notice is taken in the chapter devoted to Mixing, as it is evident, upon a moment's thought, that correct manipulation alone can cause the finer aggregate to assume its correct position in respect to the coarser.

The adequacy of matrix, or the use of a sufficient quantity of cement to fill the voids in the fine aggregate, is not only one of the indispensable means of producing strength, but is the most potent of all means for securing impermeability, inasmuch as it is the cement alone which can so thoroughly seal the pores of a block that water may not pass. Too much attention has been given to means for reducing the amount of cement used in making blocks. Inasmuch as cement is the most expensive of the raw materials, and hence constitutes a considerable item in the total cost of production, it has been thought advisable by the promoters of this industry to adopt every means for its saving. The danger-line has too often been passed. It is not chiefly cheapness, but more especially excellence, which will raise the concrete block to an important place among building materials.

On every hand the effect of improper condensation is visible. Out of a hundred concrete blocks of ordinary manufacture, how many do not disclose, on close and careful examination, an unequal degree of compactness in different sections, and how many are free from pores on the surface? It is plain that this is primarily due to the intermittence of energetic and languid

tamping, and hence we have as remedies the pneumatic tamper on the one hand and the mechanical and hydraulic presses on the other. While the hydraulic press makes a strong point of its heavy pressure, it would seem to be excessive, as it is evident that there is a limit to the amount of pressure which can be advantageously employed. If the particles are brought close together it is sufficient; and any considerable excess of pressure must force the plastic cement from between the particles it should bond, or cause fracture of arched aggregates. It would seem that the rational solution of condensation is reached in those presses which apply a reasonable pressure.

CHAPTER XVIII.

QUALITIES OF CONCRETE BLOCKS.

First in importance of the qualities of concrete blocks is that freedom from cracks, deformation, and disintegration which cannot be better defined than by the comprehensive word "soundness." Whatever be the other qualities of a block, it is valueless without soundness; whatever be its defects, it is good for something if sound. It is scarcely necessary to say that a first requisite of a sound block is a sound cement. Of this matter enough has been said in the chapter on Cement. Of the quantity of cement it may be added, to what has already been stated in the chapter devoted to Proportioning and the chapter on Voids, that the cement must thoroughly coat the aggregate in order to exercise its cementitious or bonding function, which is so essential to a sound concrete block.

The matter of mixing also has a direct action upon the ultimate quality, and that in the respect last mentioned.

It is in the handling and curing of blocks after manufacture, however, that unsoundness is most often developed. In transferring blocks to the racks, cars, and curing-yard, latent defects and invisible cracks are developed which ultimately cause the loss of the entire block, or, if a rigid inspection of the finished product be omitted, may result in failure of the member in time of need. It should be remembered that a crack in a freshly

made block never heals, but rather tends to extend through the block. Hence too much care of green blocks cannot be exercised, and the slightest defect should cause the block to be immediately returned to the mixing-platform, or, if the cement has already set, it should go to the scrap-pile.

In curing, lack of uniform conditions of moisture and shade, as well as air-drafts, are responsible for a large percentage of both surface and structural cracks; while the failure to properly dispose blocks for curing, allowing them to rest on uneven surfaces, or in contact with one another, while green, permits warping and results in twisted blocks.

In general it may be said that soundness results from those methods of manufacture securing perfect homogeneity of mass, and those methods of curing securing uniform treatment to every portion of the block.

Strength is the quality by which concrete blocks will be most usually judged in making comparisons with other building materials. By the thorough filling of voids, already so strongly recommended, great compressive strength may be obtained, while tensile strength approximating the capacity of neat cement briquettes may be attained by increasing the proportion of cement in the aggregate. It must, however, be remembered that concrete blocks, like all other materials, have their obvious uses and their fixed limitations. It is not usually necessary, therefore, to give great thought to tensile strength, except in so far as concerns the resistance to lateral stress which a wall is designed to withstand. It is usual to make provision by metal reinforcement for the resistance of transverse strain and the distribution of concentrated loads. This by reason of the greater economy of metal in tension than in compression. There is little difference in the compressive and tensile strength of steel, while concrete is from eight to ten times stronger in the former than in

the latter. It is therefore plain that the especial function of the concrete block is in the carrying of direct vertical loads.

Of course no concrete will exceed the strength of its aggregate; but if proper aggregate be used in relatively correct proportions, with an adequate amount of cement and sufficient water to secure thorough crystallization, if the manipulation of the mass in mixing be thorough and intelligent and the block be properly condensed and properly cured, there is no reason why blocks should fail, at an age of twenty-eight days, to test from 2,000 to 3,000 pounds per square inch of solid surface, i.e., making no allowance for the hollow space in the wall. The fact that individual tests have been made as high as 2,600 pounds to the square inch, on blocks selected from lots commercially made, shows the practical possibilities of good work on correct lines. The fact that most tests reported, upon a collection of blocks from various makers, show results far below these figures, indicates either that many processes are impractical for high-grade work or that many operators are careless and incompetent.

Density has a direct relation to strength and an indirect relation to impermeability. Density refers to the total percentage of solid material in the block, being opposed to porosity, which is the total percentage of voids. While mixing and condensation are quite as necessary elements in the securing of density as in the attainment of other desirable qualities of concrete blocks, it is especially the relation of proportioning to density which requires elucidation. It has already been stated that a fine aggregate possesses no greater density than a coarse one, providing each be of the same uniformity of grain. It must now be observed that the introduction of a reasonable quantity of coarse aggregate into the fine positively increases its density. That is to say, if into a quart of sand one introduces a pint of

gravel, the density is increased by the amount of voids in that amount of sand replaced by the solid contents of the gravel.

Impermeability is an essential quality in a good concrete block. The means of securing impermeability are so closely interwoven with previous observations that it is necessary to say only that it rests upon the use of an adequate proportion of cement, sufficiency of water, thorough mixing, proper gradation of aggregate, thorough condensation, and careful curing. Given these conditions and a concrete block will be more impermeable than the average of other building materials. The difference between density and impermeability lies in the fact that the latter is determined by the size and continuity of voids rather than by their total percentage. It is therefore evident that a fair proportion of fine sand or screenings is more essential to impermeability than to density, and in both may be observed the importance of the rules given for proportioning. It is also well to remember the increased impermeability that may be secured by using a small proportion of hydrated lime. Indeed, many believe that herein lies the most practicable method of overcoming permeability. No standard building material is, of itself, waterproof in the fullest sense of that much-abused word. Neither is it desirable that it should be so, as the result would be sweating of the interior due to failure to absorb the moisture developed on the inner surface. It has, however, been the desire of block-makers to render their product so far superior to brick in this respect that the customary furring and lathing might be eliminated, and the cost of construction reduced, by permitting the application of plaster directly to the concrete blocks. It seems that the only means so far adopted insuring absolute and permanent satisfaction is the use of a wall so constructed that there shall be a continuous horizontal air-space, precluding the passage of moisture, between the outer and inner face. It is, of

course, true that many preparations are offered, both as ingredients in the mixture and as washes to be used on the exterior after completion of construction; but there are serious questions yet undecided as to the deleterious action of the former and the permanence of the latter.

The fire-resisting quality of concrete blocks is, month by month, becoming more marked and more thoroughly recognized. In the early days of the use of concrete for the construction of buildings, little thought was given to its power as a fire-resistant; and it was generally assumed that, being a hydrated product, it would disintegrate at a lower temperature than the clay products, in which excessive heat created no chemical action. It was, of course, known that building-stones would spall under the extremes of heat and the copious application of water, and that the shell or matrix, which in really well-made concrete protected the aggregate, greatly reduced the tendency to disintegrate. It was not, however, until the Baltimore fire left ruins of concrete structures in condition far superior to other so-called fireproof construction that the attention of insurance experts was seriously centered upon concrete as the fireproof building material of the future. It was then found by exhaustive experiments and observations that concrete did not give off its water of chemical composition so readily as had been supposed, but that an approximate temperature of 1000° Fahrenheit was necessary to dehydrate the outer quarter inch, and this quarter inch, so dehydrated, became non-conductive, making it still more difficult to dehydrate the interior which it protected. It is true that examples of concrete-block buildings which have withstood actual fires are somewhat meager. Fig. 22 shows a building which withstood a fire at Carbon, Indiana, and from the illustration it will be noted how complete was the surrounding devastation. Fig. 23 shows a building which similarly withstood a

conflagration at Estherville, Iowa. Concerning the former it is stated that no damage was done except the breakage of window-

FIG. 22.—Ruins of Carbon, Indiana, Fire.

glass by the intense heat. Concerning the latter it is reported that, while the fiercest flames from a large adjoining building were attacking the outside, the inner side of the wall was so

slightly heated that the hand could be held against it. It must not be forgotten that, while it is the quality of concrete itself which prevents its destruction by fire, it is due to the interior air-space of the wall that the heat is not transmitted to the interior being but a special application of the same principle which makes a concrete-block house warm in winter and cool in summer. It must also be remembered that the greater the air-space, and

FIG. 23.—Ruins of Estherville Fire.

the more nearly continuous it be, the less will be the heat conductivity of the wall.

While vast sums are annually expended to secure, in the better class of buildings, some freedom from transmission of sound, this desirable result is obtained with no additional expense, but becomes merely an incidental matter, by the use of concrete-block walls.

It is likewise incident to this class of construction that vermin find no harbor in its walls. Indeed, the general sanitary conditions of concrete-block construction are so much a matter of course that their real excellence is scarcely appreciated.

There is no other class of construction in use at the present day which offers such marked capacity for scientific ventilation by properly located interior and exterior ventilators communicating through the hollow spaces of the wall, but overcoming the harshness of a direct draft of air.

Of the durability of concrete blocks much may be said and little may be necessary. It is known to readers of this book that concrete buildings have stood in perfect condition in various European countries for hundreds of years, while the ruins of ancient cities show many evidences of concrete work in a good state of preservation after thousands of years. The reader may well ask if the concrete blocks of to-day are made with the same care, and if they will possess the same degree of durability. Answer may be made in the affirmative for some, and must needs be in the negative for others. The industry is, however, capable of elevation to that high standard where an affirmative answer may soon be applicable to all; and it is the chief purpose of this treatise to influence some block-makers toward that intelligent and careful manufacture which shall eventually bring this great industry in its entirety to that high plane.

CHAPTER XIX.

TESTING BLOCKS.

It is a curious fact that most operators of concrete-block plants utterly neglect the matter of testing their product. It does not appear that their negligence is caused by any lack of faith in the quality of the blocks, or in their ability to withstand the tests, but merely because the lack of technical training has not impressed the average concrete-block maker with the value of proper tests. He hears of cement-testing, and glances at the results of tests made upon the particular brand of cement he is using—and stops there. He fails to recognize that every part of the process of making blocks, from the time the raw materials reach his yard until the finished blocks are in the wall, as well as every shovelful of material in the blocks, has a definite relation to the tests which the blocks will pass. He fails to recognize the fact that his processes may be immeasurably improved by tests which will warn him as to wherein lies his weakness. If, on the other hand, he is sure he has no weakness, tests will show to the public, whose trade he solicits, how far the material he offers excels competing building materials. It is of especial advantage to the man who is making thoroughly good blocks to have properly certified tests of his product in comparison with all other building materials in common use in his locality.

The exhaustive researches made in connection with the testing-laboratories of the city of Philadelphia have resulted

in specifications of such excellence for the testing of concrete blocks that the reader cannot be better advised as to complete tests than by a careful study of sections three to fourteen, inclusive, of the "Specifications Governing the Method of Testing Hollow Concrete Blocks used under the Supervision of the Bureau of Building Inspection of the city of Philadelphia."

They are as follows:

3. The material must be subjected to the following tests: Transverse, Compression, Absorption, Freezing, and Fire. Additional tests may be called for when, in the judgment of the Chief of the Bureau of Building Inspection, the same may be necessary. All such tests must be made in some laboratory of recognized standing, under the supervision of the engineer of the Bureau of Building Inspection. The tests will be made at the expense of the applicant.

4. The results of the tests, whether satisfactory or not, must be placed on file in the Bureau of Building Inspection. They shall be open to inspection upon application to the Chief of the Bureau, but need not necessarily be published.

5. For the purpose of tests, at least twenty (20) samples or test-pieces must be provided. Such samples must represent the ordinary commercial product. They may be selected from stock by the Chief of the Bureau of Building Inspection, or his representative, or may be made in his presence at his discretion. The samples must be of the regular size and shape used in construction. In cases where the material is made and used in special shapes and forms too large for testing in the ordinary machines, smaller-sized specimens shall be used, as may be directed by the Chief of the Bureau of Building Inspection, to determine the physical characteristics specified in Section 3.

6. The samples may be tested as soon as desired by the applicant, but in no case later than sixty days after manufacture.

7. The weight per cubic foot of the material must be determined.

8. Tests shall be made in series of at least five, except that in the fire-tests a series of two (four samples) are sufficient. Transverse tests shall be made on full-sized samples. Half samples may be used for the crushing, freezing, and fire tests. The remaining samples are kept in reserve, in case unusual flaws or exceptional or abnormal conditions make it necessary to discard certain of the tests. All samples must be marked for identification and comparison.

9. The transverse test shall be made as follows: The sample shall be placed flatwise on two rounded knife-edge bearings set parallel, seven inches apart. A load is then applied on top, midway between the supports, and transmitted through a similar rounded knife-edge, until the sample is ruptured. The modulus of rupture shall then be determined by multiplying the total breaking load in pounds by twenty-one (three times the distance between supports in inches), and then dividing the result thus obtained by twice the product of the width in inches by the square of the depth in inches. No allowance shall be made in figuring the modulus of rupture for the hollow spaces.

10. The compression test shall be made as follows: Samples must be cut from blocks so as to contain a full-web section. The sample must be carefully measured, then bedded flatwise in plaster of Paris to secure a uniform bearing in the testing-machine and crushed. The total breaking-load is then divided by the area in compression in square inches; no deduction to be made for hollow spaces; the area will be considered as the product of the width by the length.

11. The absorption-test shall be made as follows: The sample is first thoroughly dried to a constant weight. The weight must be carefully recorded. It is then placed in a pan or tray of water,

face downward, immersing it to a depth of not more than one-half inch. It is again carefully weighed at the following periods: Thirty minutes, four hours, and forty-eight hours, respectively, from the time of immersion, being replaced in the water in each case as soon as the weight is taken. Its compressive strength, while still wet, is then determined at the end of the forty-eight-hour period, in the manner specified in Section 10.

12. The freezing-tests are made as follows: The sample is immersed, as described in Section 11, for at least four hours and then weighed. It is then placed in a feezing-mixture or a refrigerator, or otherwise subjected to a temperature of less than 15 degrees F. for at least twelve hours. It is then removed and placed in water, where it must remain for at least one hour, the temperature of which is at least 150 degrees F. This operation is repeated ten (10) times, after which the sample is again weighed, while still wet from the last thawing. Its crushing strength should then be determined as called for in Section 10.

13. The fire-test must be made as follows: Two samples are placed in a cold furnace in which the temperature is gradually raised to 1700 degrees F., and the test-piece must be subjected to this temperature for at least thirty minutes. One of the samples is then plunged in cold water (about 50 degrees to 60 degrees F.) and the results noted. The second sample is permitted to cool gradually in air and the results noted.

14. The following requirements must be met to secure an acceptance of materials. The modulus of rupture for concrete blocks at twenty-eight days old must average one hundred and fifty, and must not fall below one hundred in any case. The ultimate compressive strength at twenty-eight days must average one thousand pounds per square inch, and must not fall below seven hundred in any case. The percentage of absorption (being the weight of water absorbed divided by the weight of the dry sample) must

not average higher than 15%, and must not exceed 20% in any case. The reduction of compressive strength must not be more than thirty-three and one-third per cent., except that, when the lower figure is still above one thousand pounds per square inch,

Fig. 24.—Column Demonstrating Compressive and Lateral Strength.

the loss in strength may be neglected. The freezing and thawing process must not cause a loss in weight greater than ten per cent., nor a loss in strength of more than thirty-three and one-third per cent., except that, when the lower figure is still above one thousand pounds per square inch. thou-

sand pounds per square inch, the loss in strength may be neglected. The fire-test must not cause the material to disintegrate.

It is the practice of very many manufacturers to erect permanent exhibits of concrete blocks in which a practical test of one or more of the essential qualities of good blocks is embodied. To many these tests are more convincing than are the certified laboratory tests, because of their unfamiliarity with the methods of conducting the latter, and their habit of believing only in that which they see. In Fig. 24 is presented a very interesting demonstration of the resistance of a perfectly bonded wall to lateral strain, as well as the capability of concrete blocks to support heavy loads. This column, which was erected by a St Louis operator, is six feet square and twenty feet high, having an interior area of sixteen square feet. The column is loaded with dry sand. The total weight of one hundred thousand pounds is carried by eight feet of 12″ wall, 50% hollow.

CHAPTER XX.

BLOCK USES.

The illustrations used in connection with this chapter are sufficient evidence of the adaptability of concrete blocks to all

FIG. 25.—Methodist Church, McCook, Nebraska.

classes of building construction, and of their satisfactory employment in completed structures of various kinds and sizes throughout the United States.

FIG. 26.—Entrance to Cottage Hill Cemetery, Brazil, Indiana.

FIG. 27.—Cottage, Nashville, Tennessee.

FIG. 28.—Church at North Liberty, Indiana.

Figs. 26 and 35 show entrance gates. Figs. 25 and 28 give views of churches. Figs. 27, 29 to 32, and 34 illustrate some of the various designs in residences. In Fig. 33 is shown an office-building, and in Fig. 36 a state institution.

This list might easily be multiplied, but the illustrations presented have been selected from a large collection as sufficiently emphasizing the capacity of the concrete block for any style of structure. For dwelling-houses there can be no building material at any price which will afford so great ultimate satisfaction. The introduction of a fireproof material in the construction of dwellings of moderate size is an innovation, and the departure from the time-honored fire-trap construction for the homes of the great masses of the people is welcomed on all sides.

Perhaps the reader will pardon a moment's digression, and consider what it means to the average well-to-do American farmer of to-day, isolated from the fire protection of our cities, to have a building material which protects him from that enemy which he most fears. How long a step it is from the frame-houses with which the countryside is dotted, and which are a constant menace to the lives and property of the occupants, to concrete-block construction, which presents the greatest fire-resisting qualities, and which may be secured at but slightly increased initial cost, while the subsequent freedom from paint and repairs makes the ultimate expenditure less than for wooden buildings! Similar construction, but of plainer and less expensive type, is adapted to barns and all accessory buildings.

To those who dwell in cities, the fireproof quality of concrete blocks appeals quite as strongly, since reliance, in fierce conflagrations, must at last rest upon the integrity of the individual building.

In the construction of buildings intended to house stocks of

merchandise, the argument applies with even stronger financial force. If, as is often the case in smaller establishments, the store be left without a watchman at night, one's all may be at the mercy of the power of the building to resist the flames. How small the protection afforded the merchant by the average building occupied for mercantile purposes!

FIG. 29.—Residence, Nashville, Tennessee.

Sight must not be lost of those other superior qualities which make block construction so eminently useful. The lightness of walls in proportion to the load they will carry with a satisfactory factor of safety; the low degree of heat conductivity which renders a home, a church, or a public building comfortable during the heated term and saves 25% of the winter's fuel bill; the protection from transmission of sound, which will be appreciated by careful builders; the facility with which pipes and wires

FIG. 30.—Residence at Warsaw, Indiana.

Fig. 31.—A Home at Port Washington, Wisconsin.

FIG. 32.—Residence at Denver, Colorado.

FIG. 33.—Warburton Building, Tacoma, Washington.

may be laid in the hollow walls, and the ease with which they may be reached for repair if suitably disposed openings be arranged when building, with covers quickly removable in case of necessity;

FIG. 34.—Residence in Columbus, Ohio.

the freedom from moisture, which appeals alike to one who seeks comfort or health and to one who seeks economy by elimination of furring and lathing; the adaptability of blocks to any

FIG. 35.—Entrance to Fairview, Bluffton, Indiana.

shape or size, which secures the builder's good will; the appearance of really good blocks and the readiness with which they yield to artistic decorative features, which are sources of delight to the architect,—all these, and more, are the reasons which account for the adoption of concrete blocks in the buildings

FIG. 36.—Nebraska State Normal School, Kearney, Nebraska.

illustrated, and in a very great number of other important buildings of various uses and diversified architecture.

In closing this chapter, it is desired to especially direct the reader's attention to the Nebraska State Normal School Building shown in Fig. 36, for the reason that it demonstrates the injustice of the oft-repeated criticism of certain architects that concrete blocks cannot be made to fit their plans. The plans for this structure were made in contemplation of using cut stone,

and the specifications provided for various widths of courses and fractional sizes most unusual in block construction. Those in charge of the work were quick to recognize the great opportunity here afforded the concrete-block industry to demonstrate its adaptability, and they complied with the specifications as drawn.

CHAPTER XXI.

CAUSES OF FAILURE.

In considering those causes which have in some cases led to failure in the manufacture of concrete blocks, and in other cases have prevented their successful introduction in certain localities, it is well to distinguish between the errors of the machine-manufacturer and those of the block-maker. For convenience the latter will, in this chapter, be designated as the operator and the former as tpe manufacturer.

The most culpable error of the manufacturer lies in his failure to recognize the merits of competing machines, in his real or assumed ignorance of the points of superiority which have been devised by another, and in his persistent refusal to accept certain modifications in devices or process which will enable the operator of his machine to more fully meet the public demand. It would be well for the manufacturer to realize that the public will not with patience accept what he may choose to give, but that the public will have what it desires, and what the requirements of good construction demand. If he do not anticipate that demand, and if he be not prepared to meet it, the public will go elsewhere, and, still failing to find what is sought, will devise ways and means on its own behalf, without considering the manufacturer individually or collectively.

Nowhere is this absence of consideration for the public good more apparent than in the failure of manufacturers to provide

a uniform standard of sizes for concrete blocks. There are but few machines which individually offer all that is needed in the construction of buildings, and hence, as stated in a former chapter, a good mold-maker is a requisite of a successful factory. The adherence of each manufacturer to an arbitrary size of block seems to have no better motive than the prevention of the joint use of his own machine and that of a competitor, each of which might supply those blocks most advantageously made on the respective machines. Certainly for this diversity and consequent annoyance to the public there is no reason and no excuse. If the concrete-block industry shall ever attain that universal introduction to which the inherent qualities of well-made concrete justly entitle it, and to which the added qualities peculiar to hollow concrete walls add mighty emphasis, the manufacturers must become imbued with somewhat of that spirit of co-operation which, in these latter days, is recognized as a prime factor in the development of every great industry, and which has been by no means the least of those causes which have brought success to every great enterprise of our time.

Scarcely less worthy of attention is the careless treatment which operators continually receive at the hands of those whose machines they purchase, and whose interests should be, and unalterably are, thereafter allied with their own. It should be the first consideration of the manufacturer to place machines in the hands of those, and those only, whose capital and knowledge are adequate to insure success; and it should be the second consideration to give the operator such full and complete instruction and information as will fairly aid him to attain ultimate success. It is perhaps unfair to place all of this blame on the manufacturer when so much of it is in reality chargeable to his salesmen in the field. It is impossible to consider this phase of the question without bringing up the old contention of the

commission salesman versus the salary salesman, as it is evident that self-interest will not permit the former to lose a sale to any one who is willing to buy, even though he may know that it is not for the ultimate good of the vendor or the vendee; nor can he be expected to spend his time, after consummation of a sale, in giving those instructions which are so helpful. The practice of men in the field on commission is to know barely enough of the business to enable them to effect sales. The practice of a salaried man is to know the business from alpha to omega, and to dispense that knowledge for the good of his house in connection with past, present, and future sales. To briefly summarize, it may be said that manufacturers should avoid a short-sighted policy, and should endeavor to take advantage of every opportunity to raise the quality of the work produced by their machines.

Considering the causes of failure properly chargeable to the operator, the most apparent may be said to be lack of knowledge of the nature and action of Portland cement. The man who buys a machine is, in very many instances, ignorant of cement beyond the meager and sometimes inaccurate statements of machine catalogues. It is his first duty to study cement theoretically and practically until he really knows it. The operators who have done this have been uniformly successful. Another cause of failure is reliance on cement alone, and consequent neglect as to character and proportioning of aggregate. The fixed proportions usually mentioned in manufacturers' catalogues are based merely on average conditions, and may or may not be applicable to local materials. The use of unequal percentages of water is a fruitful source of failure, as making one batch wetter than another means a variation not only in strength and density but in color as well. The proportion of water will not be the same with different aggregates, and should therefore

be determined in respect to local materials, but, when once determined, should be closely adhered to by a system of accurate measuring. Careless curing has caused a very large number of failures, and it is hoped the operator will give careful heed to the chapter devoted to that subject. Perhaps it is the inordinate desire for cheapness rather than quality which has led many block-makers astray. The constant effort should be to excel in quality, and to keep the cost at the lowest possible figure consistent with high-class work. This is merely a matter of business management and factory superintendence, and the reduction in cost should never encroach upon the real goodness of the product. Careless laying has prejudiced builders against the use of blocks otherwise satisfactory, and of this a previous chapter has dealt in detail.

Perhaps one of the greatest disadvantages of concrete blocks is their ready adaptability to any design or decorative feature. In the hands of the skillful and artistic builder, the merits of this adaptability are invaluable. In the hands of the unskilled and inartistic, the same adaptability becomes valueless, and results in such hybrid designs and grotesque architecture as to disgust those who appreciate correct lines in building. The operator must realize that the vast possibilities of concrete-block construction must not be abused, but that their use must be directed by those whose natural artistic tastes and architectural training fit them to so dispose the various decorative features that a symmetrical and pleasing structure may result.

CHAPTER XXII.

COST.

In any computation of cost in connection with the manufacture of concrete blocks, certain factors require consideration which can only be determined by an exact knowledge of local conditions. Hence the customary practice of assuming an arbitrary standard of prices becomes misleading for more reasons than are apparent to the casual reader. This is but one instance of the many mistakes which have been made in the promotion of this industry by continued effort to avoid scientific and technical methods. It will be found in actual practice that the factors which must be determined before any reliable cost calculation can be made are as follows:

1. Cost of cement.
2. Cost of sand or screenings.
3. Cost of gravel or broken stone.
4. Relative proportions of fine and coarse aggregate.
5. Exact proportion of cement.
6. Relation between volume of aggregate and volume of compact concrete.
7. Average rate of actual production per capita per day.
8. Price of different grades of labor per day.
9. Cost of hauling finished product.

10. Cost of administration:
    a. Superintendence.
    b. Advertising.
    c. Office expense.
11. Incidentals:
    d. Depreciation of plant.
    e. Repair allowance.
    f. Interest on investment.
    g. Periodicals, literature, and conventions.

Those who contemplate engaging in the manufacture of concrete blocks will view the foregoing lightly, and ask of what use is so careful an analysis. Those who have succeeded will recognize the foundation on which they have builded. Those who have failed will frankly admit that a careful study of this analysis had saved them loss.

Inasmuch as the net weight of Portland cement is 94 lbs. per bag, and the average weight per cubic foot of loose Portland cement is 92 lbs., it will be sufficiently accurate to consider the contents of a bag as one cubic foot, and this method will greatly simplify cost computation, inasmuch as sand and gravel are customarily valued by the cubic yard. The cost of fine and coarse aggregate must be separately ascertained; and the proportions in which they are to be mixed must be determined, as well as the exact proportion of cement to be incorporated. It must be observed that at every step of the process it is essential that local conditions govern. A variation in the aggregate, such as the introduction of coarser material, will often effect a material reduction in the necessary amount of cement, and result in cost-saving.

We now approach the most intricate part of the computation. It is usual for block-makers to consider that one cubic foot of gravel and a half cubic foot of sand will have a volume

of $1\frac{1}{2}$ cu. ft. when thoroughly mixed. It is a fact that a considerable portion of the sand enters the voids of the gravel and decreases the volume. The same is, of course, true of cement and sand. It is therefore evident that, owing to variation in local size, shape, and gradation of aggregate, the actual amount required to make a certain volume of mixed aggregate can only be determined by actual trial. The different materials locally available will require different percentages of water, broken stone usually taking more than gravel. Again, different sands will show different variations in volume for the same percentage of moisture. Therefore the volume of wet concrete obtainable from dry-mixed concrete can be known only from actual experiment. The different processes of manufacturing blocks, as well as the different materials used, involve varying percentages of reduction in volume by compression in molding. This, like the previous percentages, must be noted by actual observation. The most practical method of obtaining the cost of material for various blocks is to first compute the cost of a cubic yard of certain proportions of dry-unmixed materials, then by actual test ascertain the relative volume of the dry-unmixed material to the wet-mixed and compacted material. It is then easy to find the cost of material in a solid block of known dimensions, and it will be necessary to deduct the percentage of hollow space for each different width of wall. One should know exactly how much the material costs in each block he offers for sale.

It is necessary to know the average number of each kind and size of blocks which a given number of men will produce in a day—not the number they can produce on a test run. It is also essential to know the various prices paid labor, and to consider what labor is especially chargeable to a certain grade of product. This will avoid making money in one end of the fac-

tory and losing it in the other. The cost of transporting blocks from the yard to the place of use is purely a local matter, but

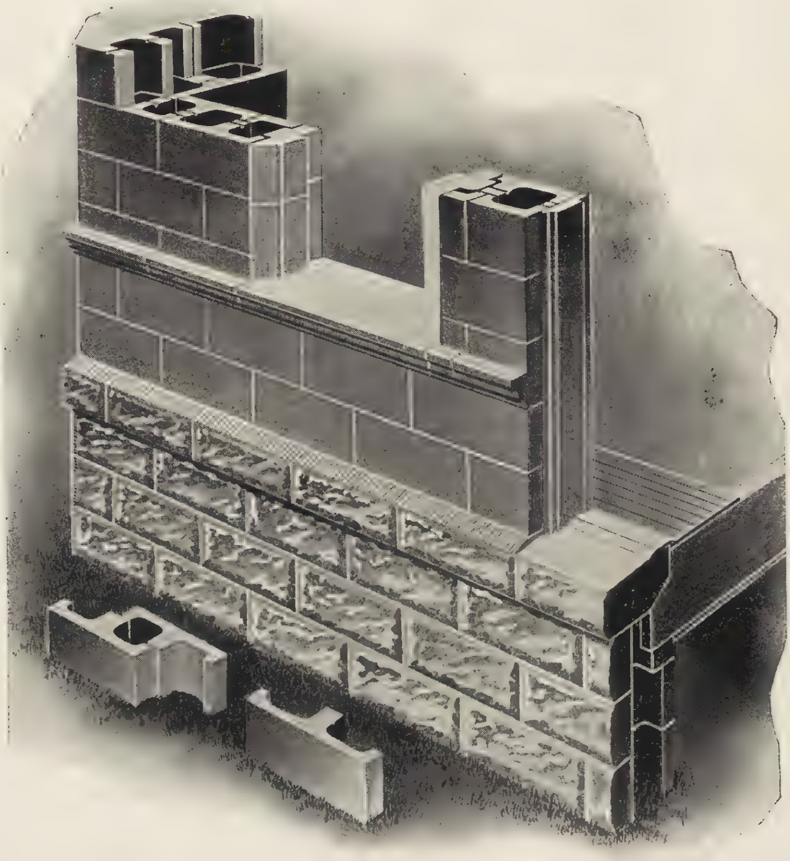

FIG. 37.—Decorative Features of Two-piece Wall.

should be allowed at a figure high enough to cover breakage loss.

The items under Administration and Incidentals are often

overlooked in arriving at manufacturing cost, but they are properly chargeable against the blocks produced, and there is not an item in the list which is not an essential expense incident to the business of every progressive operator. The point to be especially emphasized, aside from the necessity and consideration of these necessary expenses themselves, is that the amount of such estimated expenditure per annum should be charged pro rata against the estimated annual production of the plant, and not against its utmost capacity.

CHAPTER XXIII.

ARCHITECTURE.

PERHAPS there is to-day in the United States no other industry the early development of which was in the hands of those so manifestly unfitted to bring it to a high plane of success. While the problems of useful building construction were early solved in the designing of concrete-block shapes, and while a high standard of excellence therein has often been obtained and is adhered to with more or less persistence, the development of architecture, in the full meaning of the term, has been a matter receiving but little attention. For this two valid reasons are assignable. The first is the lack of recognition, on the part of block-makers and machine-manufacturers, of those principles of symmetry and decorative fitness which can alone result in a building beautiful to one trained to judge of beauty from the view-point of the architect. The second is the lack of attention, by architects, to a building material the early examples of which repelled them by the hideous external appearance, and caused them to pass by on the other side, unmindful of the latent possibilities of this style of construction, which only awaited the touch of a master hand to so transform it that buildings beautiful and harmonious in every part might result.

The first idea which presented itself to the bunglers of bygone days was that in concrete blocks they had found an artificial stone; and so intent were they on impressing the world

with the fact that it was really stone that they forthwith hastened to devise ways and means for imitating the roughest class of

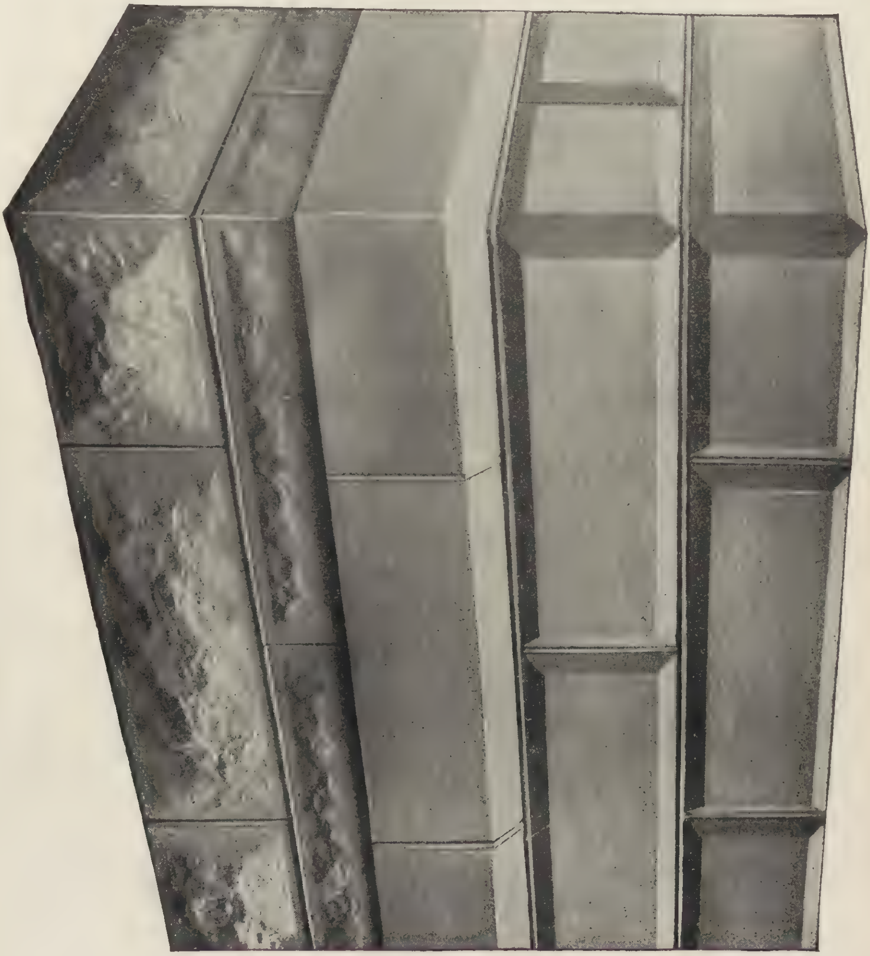

FIG. 38.—Beautiful Decoration in Concrete Blocks.

stone-work. In this they overshot the mark, for the imitation became but a cheap and tawdry thing lacking the essential variety

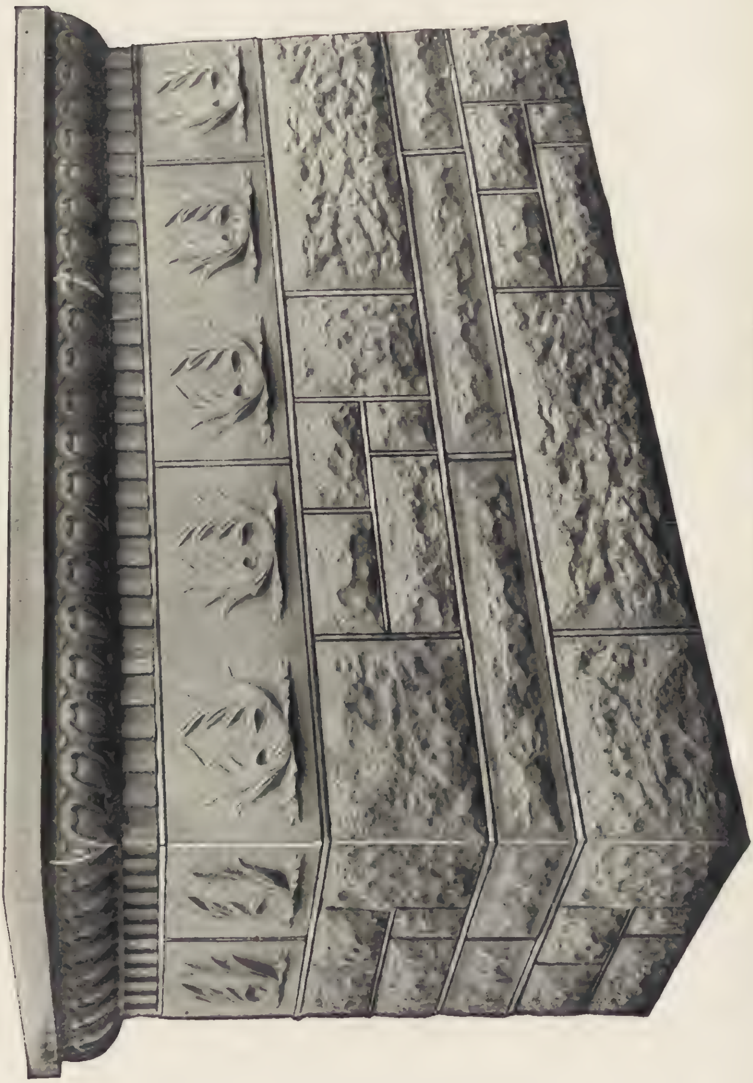

FIG. 39.—Ornamentation of a Pitch-face Wall.

and naturalness of the original. There can be but one reason assigned for the almost universal survival to the present day of the prevalent pitch-face blocks, and that is that the unfinished and broken surface makes less visible the defects of a lean, dry, porous, and ill-compacted block. The successive repetition throughout a wall of the same or very similar designs of a plastic counterfeit of hewn stone has no place in architecture. The difficulty has been that block-makers have not understood that so-called ornamentation cannot consistently be spread over a wall. They have failed to recognize, in respect of decoration, the dignity of plain-wall blocks and their importance as an imposing decorative factor. Either plain-wall blocks or bevel-edge blocks constitute a background of inestimable value in accentuating ornamentation for decorative purposes; and not only do they make better work a necessity, but eliminate the idea of cheap imitation of a cheap grade of stone-work. In this connection nothing is more valuable than a careful study of some of the structures of the Italian Renaissance; and the accentuation of mortar-joints in some of the block-stone rustication of that period is of especial interest to the progressive block-maker of to-day.

In a previous chapter sufficient consideration has been given to ornamental work and the methods of its manufacture. It is not within the scope of this chapter to further discuss that distinct branch of the cement-block industry, but rather to present for the operator's consideration the distinction between ornamentation and decoration. These terms are jumbled in the mind of the average operator in a manner indicating synonymous meaning. It must be comprehended that decoration involves a balanced contrast of members in which the plainness of certain portions of the building is quite as essential to the harmonious beauty of the whole as is the elaborate ornamentation.

CHAPTER XXIV.

BUILDING CONSTRUCTION.

The first consideration of any system of building construction is a firm foundation. Excavation should be made to a soil of constant position and volume, and thereon should be laid solid concrete footings the height of which is determined by the character of the soil, and the width calculated in the usual manner by the resistance of the soil in proportion to the weight to be sustained. Upon the footing of solid and wet concrete, allowed to become well hardened, should be laid the basement walls of concrete blocks. If the basement walls are expected to act in any degree as retaining-walls, cross-walls should if possible divide the space. If, however, the intended use of the building renders this impracticable, interior pilasters should occur at such intervals as may be necessary to resist the strain upon the walls.

The method of supporting joists and girders differs with different systems of block-manufacture, but usually contemplates either a narrower course of blocks at joist-ends, the insertion of the joists into the walls with small blocks between joists, or the use of steel stirrups or joist-hangers hung in the wall, in much the same manner as common in brick-construction. Inasmuch as hollow concrete walls afford one of the most fire-resisting of known building materials, it is important that all timbers be hung free, so that the failure of a floor in case of interior fire may not exert a strain upon the walls. Where the concentrated

load upon a given area of hollow wall does not allow a sufficient factor of safety, the blocks for from one to three courses thereunder must be made solid, or reinforced with steel sufficient to increase the modulus of rupture, so that the load may be distributed throughout the wall.

It may also be mentioned that, if a thoroughly fireproof building be desired, floors should be of reinforced concrete.

The width of wall for the superstructure, as well as the basement, will usually be regulated by city ordinance, and in few places are widths required in excess of those specified for walls

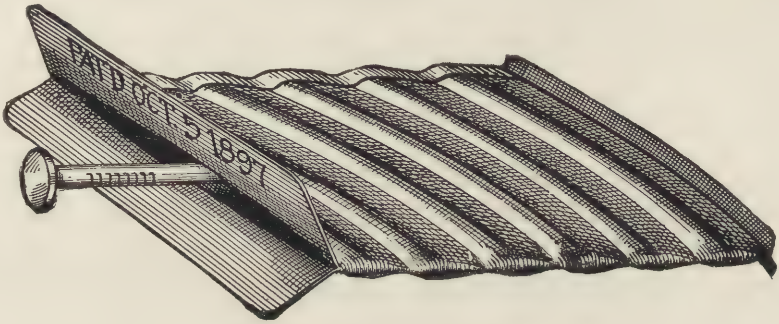

FIG. 40.—Metal Wall-plug.

of brick. In the absence of such regulations one may safely use 8″, 10″, 12″, and 15″ walls, reading in the order given for the first story of any height up to a four-story building, and reading inversely for the thickness of successive stories; e.g., given a three-story building, the first story will be the third number, or 12″, and, reading inversely, the respective widths of first, second, and third stories is seen to be 12″, 10″, and 8″.

There is no especial object in using concrete-block partitions, except in fireproof construction. In that case they should be 6″ if bearing-partitions, and 4″ if not.

In Fig. 40 is shown the device which is usually inserted in

mortar-joints for nailing window- and door-trim, base-boards, picture-molding, and the like to the walls. It is very clever, and worthy the attention of every operator.

FIG. 41.—Various Shapes and Designs.

In every system of block-construction there are a multiplicity of shapes for different purposes, such as corners, window- and

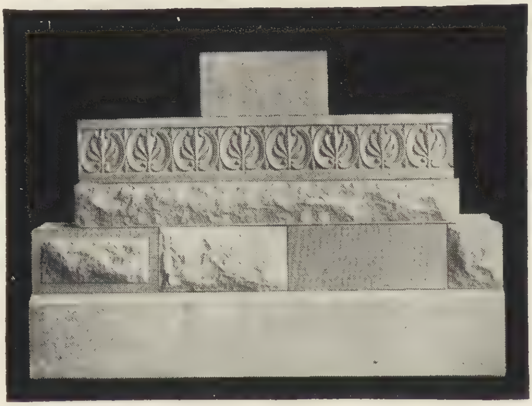

FIG. 42.—Variety in Size and Style.

door-jambs, bay-window angles, and arches. In Fig. 41 a variety of shapes are shown, but to give details of all special blocks

covered by adjustability of the many machines on the market is manifestly impossible; and it is likewise unnecessary, as the manufacturers' catalogues supply ample information upon this matter.

To the successful maker of concrete blocks there is no single matter of greater importance in the securing of business and the winning of architects' approval than the ability to follow plans, and to make from a blue-print each and every block required for a building with such exactness that no sound of chisel or hammer may be heard in the cutting of blocks to fit their appointed places. It must never be supposed that an architect will prepare his plans to fit the particular sizes of blocks which it may suit the convenience of the block-maker to supply. The latter must be able to make blocks to fit the plans of the architect, or go out of business.

CHAPTER XXV.

BUILDING REGULATIONS.

In the preparation of this chapter a careful review of all accessible building ordinances of the larger cities in the United States has revealed the fact that, in so far as concerns concrete-block manufacture, they are reduced to two classes, of which the most notable respective examples, and those indicating the most exhaustive study in preparation, are Philadelphia and Denver. These are accordingly here represented.

PHILADELPHIA.

1. Hollow concrete building-blocks may be used for buildings six stories or less in height where said use is approved by the Bureau of Building Inspection, provided, however, that such blocks shall be composed of at least one (1) part of standard Portland cement, and not to exceed five (5) parts of clean, coarse, sharp sand or gravel, or a mixture of at least one part of Portland cement to five (5) parts of crushed rock or other suitable aggregate; provided further that this section shall not permit the use of hollow blocks in party-walls. Said party-walls must be built solid.

2. All material to be of such fineness as to pass a one-half-inch ring, and be free from dirt or foreign matter. The material composing such blocks shall be properly mixed and manipu-

lated, and the hollow space in said blocks shall not exceed the percentage given in the following table for different-height walls, and in no case shall the walls or webs of the block be less in thickness than one-fourth of the height. The figures given in the table represent the percentage of such hollow space for different-height walls:

Stories	1st	2d	3d	4th	5th	6th
1 and 2	33	33				
3 and 4	25	33	33	33		
5 and 6	20	25	25	33	33	33

3. The thickness of walls for any building where hollow concrete blocks are used shall not be less than is required by law for brick walls.

4. Where the face only is of hollow concrete building-block and the backing is of brick, the facing of hollow concrete blocks must be strongly bonded to the brick, either with headers projecting four inches into the brick-work, every fourth course being a heading course, or with approved ties, no brick backing to be less than eight inches. Where the walls are made entirely of hollow concrete blocks, but where said blocks have not the same width as the wall, every fifth course shall extend through the wall, forming a secure bond. All nails where blocks are used shall be laid up in Portland cement-mortar.

5. All hollow concrete building-blocks, before being used in the construction of any buildings in the city of Philadelphia, shall have attained the age of at least three (3) weeks.

6. Wherever girders or joists rest upon walls so that there is a concentrated load on the block of over two (2) tons, the blocks supporting the girder or joists must be made solid. Where such concentrated load shall exceed five (5) tons, the blocks for two (2) courses below, and for a distance extending at least

eighteen (18) inches each side of, said girder shall be made solid Where the load on the wall from the girder exceeds five (5) tons, the blocks for three (3) courses underneath it shall be made solid with similar material as in the blocks. Wherever walls are decreased in thickness, the top course of the thicker wall to be made solid.

7. Provided always that no wall or any part thereof composed of hollow concrete blocks shall be loaded to an excess of eight (8) tons per superficial foot of the area of such blocks, including the weight of the wall; and no blocks shall be used that have an average crushing strength less than 1,000 pounds per square inch of area at the age of twenty-eight days, no deduction to be made in figuring the area for the hollow spaces.

8. All piers and buttresses that support loads in excess of five (5) tons shall be built of solid concrete blocks for such distance below as may be required by the Bureau of Building Inspection. Concrete lintels and sills shall be reinforced by iron or steel rods in a manner satisfactory to the Bureau of Building Inspection; and any lintels spanning over four feet six inches in the clear shall rest on solid concrete blocks.

9. Provided that no hollow concrete building-blocks shall be used in the construction of any building in the city of Philadelphia unless the maker of said blocks has submitted his product to the full test required by the Bureau of Building Inspection, and placed on file with said Bureau of Building Inspection a certificate from a reliable testing-laboratory showing that samples from the lot of blocks to be used have successfully passed the requirements of the Bureau of Building Inspection, and filing a full copy of the test with the bureau.

10. A brand or mark of identification must be impressed in, or otherwise permanently attached to, each block for purpose of identification.

11. No certificate of approval shall be considered in force for more than four months unless there be filed with the Bureau of Building Inspection in the city of Philadelphia, at least once every four months following, a certification from some reliable physical testing-laboratory showing that the average of three (3) specimens tested for compression and three (3) specimens tested for transverse strength comply with the requirements of the Bureau of Building Inspection of the city of Philadelphia, said samples to be selected either by a building-inspector or by the laboratory from blocks actually going into construction work. Samples must not be furnished by the contractors or builders.

12. The manufacturer and user of any such hollow concrete blocks as are mentioned in this regulation, or either of them, shall at any time have made such tests of the cements used in making such blocks, or such further tests of the completed blocks, or of each of these, at their own expense, and under the supervision of the Bureau of Building Inspection, as the chief of said bureau shall require.

13. The cement used in making said blocks shall be Portland cement, and must be capable of passing the minimum requirements as set forth in the "Standard Specifications for Cement" by the American Society for Testing Materials.

14. Any and all blocks, samples of which, on being tested under the direction of the Bureau of Building Inspection, fail to stand at twenty-eight days the tests required by this regulation, shall be marked "Condemned" by the manufacturer or user and shall be destroyed.

15. No concrete blocks shall be used in the construction of any building within the city of Philadelphia until they shall have been inspected, and average samples of the lot tested approved and accepted by the chief of the Bureau of Building Inspection.

DENVER.

Section 167.—Blocks of Portland cement and sand, or of Portland cement, sand, and gravel or crushed stone, may be substituted for brick for building the walls of buildings under the following conditions:

Walls built of cement-and-sand blocks shall be of the same thickness as specified for brick walls, except that the block walls may be 8″, 12″, 16″, 20″, and 24″ thick, in place of 9″, 13″, 17″, 22″, 26″ as specified for brick.

Walls built of cement, sand, and gravel, or crushed stone, under what is known as the two-piece system of construction, shall be of the same thickness as specified for brick walls, except that an eight (8) inch block wall may be used in place of a nine (9) inch brick wall, a ten (10) inch block wall in place of a thirteen (13) inch brick wall, a twelve (12) inch block wall in place of a seventeen (17) inch brick wall, and a fifteen (15) inch block wall in place of a twenty-one (21) inch brick wall.

Section 168.—Cement-and-sand blocks, made on the one-piece method of construction, shall not have hollow spaces exceeding one-third (⅓) the area of the block, and the outer walls of the block shall not be less than two (2) inches thick. The composition of the blocks shall be as follows, viz.:

One (1) story buildings, one (1) part Portland cement and not more than five (5) parts coarse, sharp sand.

Two (2) story buildings, one (1) part Portland cement and not more than four (4) parts coarse, sharp sand.

Three (3) and four (4) story buildings with basement, one (1) part Portland cement and not more than three (3) parts coarse, sharp sand.

All blocks must be thoroughly tamped in the molds, and put

under a sufficient hydraulic pressure when required before removing the block from the mold.

Section 169.—Blocks made on the two-piece method of construction shall have an outer face not less than one and five-eighths ($1\frac{5}{8}$) inch thick for eight (8) inch walls, and two (2) inches thick for ten, twelve, and seventeen (10″, 12″, and 17″) inch walls, and a center arm not less than three (3) inches thick.

Blocks of this class shall be composed of Portland cement, sand, and gravel, in the proportion of one (1) part Portland cement to not more than six (6) parts of sand and gravel or broken stone and not less than 7.8 per cent. water; each block shall be made under a pressure of at least thirty (30) tons.

Section 170.—No cement blocks shall be used in a building until they have been cured by being kept moist for twenty (20) days from the time they are taken from the mold, and said blocks during that time must not be allowed to dry out.

Section 171.—The building-inspector may at any time require a certified test of the cement blocks being furnished for a wall or partition showing a crushing strength of at least one thousand (1,000) pounds to the square inch, on a section of block nine (9) inches high, and any blocks not meeting this test shall be condemned as unfit for use.

Section 172.—Chimneys and flues built of cement blocks shall conform to the requirements for brick flues as to flue-lining and thickness of walls, except that six (6) inches of solid concrete shall be considered as equivalent to eight or nine (8 or 9) inches of brick-work.

Section 173.—All concrete or cement walls will have at level of floor or roof timbers a plate course, to level each floor, same to be hollow, four (4) by four (4) inches, all bonded and set in cement.

All blocks required for joist- or beam-filling must be of the required dimensions to fit snug against and level with the top of joist. All concrete-block walls and piers will be limited to a safe load of ten (10) tons per square superficial foot; and all piers supporting end of beams, girders, etc., must have the hollow spaces in same filled solid with concrete mixed as before specified, and tamped solid every three (3) feet in height as the pier is being built.

Section 174.—All centering shall be self-supporting, and no center in concrete construction shall be struck until seven (7) days after the concrete is laid.

Section 175.—All concrete and cement walls must be set with Portland cement-mortar, mixed in the proportion of one (1) part of cement to not more than three (3) parts of sand; and each bed of cement must not be less than one-quarter ($\frac{1}{4}$) inch. Point the joints on outside of walls with similar cement-mortar. All blocks must break bond when laid in the walls.

Section 176.—No materials containing cement, that may have set or partially set, can be used in a new batch, and must be immediately discarded and thrown out.

All blocks that may be damaged or shattered from the effects of cutting or handling will not be allowed to be used in any building, and must be removed immediately if required by the building-inspector.

Section 177.—All structural concrete exposed to or worked in the outer air shall not be worked when the temperature is 32 degrees F. or less in the shade; and any concrete liable to be exposed to frost or snow or ice, before it has attained its permanent set, shall be temporarily protected until the season has advanced beyond the probability of a frost, or until the building is properly enclosed; and all such work, after center is removed,

shall be given a physical test that will sustain a load of three (3) times that for which it is designed, without sign of flaw or failure.

Upon the subject of Building Regulations the following extract is made from an article by the author published in the *Cement Age* of January, 1906:

The rapid growth of the cement block-industry, and especially its introduction in cases of large and important buildings in great commercial centers, has awakened great interest in the passage of building ordinances designed to protect the public against unscrupulous operators. In many places the tendency has been to disregard the improvements made in recent years by the application of scientific methods of proportioning, mixing, compressing, and curing concrete blocks, and to subject the industry to standards which, if not entirely fair, were at least safe in those bygone days when the art of concrete construction was not based upon an exact science.

With the degree of engineering talent engaged in the industry at the present time, with the present knowledge of processes and methods, and with the innumerable examples of satisfactory use, it is as unfair to the public as to the block-makers to hedge the industry about with insane regulations prohibiting the use of a form of construction at once strong, durable, and fireproof, insuring buildings warm in winter, cool in summer, dry in any weather, and cheaper than any other standard form of building material of equal quality.

Minneapolis permits the use of concrete-block walls of width equal to required widths of brick walls, blocks to be of 1:5 cement and sand, or 1:2:3 cement, sand, and gravel or crushed rock; mixture of medium consistency, blocks three weeks old, hol-

low spaces from 33% to 25% according to height of walls, minimum crushing strength 700 lbs. per square inch.

Newark requires $1:1\frac{1}{2}:2\frac{1}{2}$ of standard Portland cement, sharp-grit sand free from loam or dirt, and crushed stone, slag, or gravel, all to pass $\frac{3}{4}''$ screen; maximum dimensions of blocks, $36''\times 10''\times 16''$; minimum width of wall, 8″; maximum hollow space, $33\frac{1}{3}\%$; blocks 30 days old, tensile test 150 lbs., compression 1500 lbs.

Philadelphia provides for 1:5 mixture, using any suitable aggregate; hollow space from 33% to 20%, decreasing in the lower stories as the walls increase in height; same width of wall as for brick; solid blocks under concentrated loads; and blocks to be three weeks old. The transverse, compression, absorption, freezing, and fire tests adopted by the Philadelphia bureau probably constitute the most careful revision yet made of the building-material tests of the Borough of Manhattan, the changes adapting the specifications to concrete-block construction.

Without any desire to criticise the excellent work of those eminent gentlemen who have prepared ordinances in the cities named, the author wishes to mention a few pertinent points worthy the consideration of those who may have occasion to prepare like regulations.

A mixture of $1:1\frac{1}{2}:2\frac{1}{2}$, 1:2:3 or 1:5, unless qualified, is indeterminate. Unless expressly stated to the contrary, these proportions are generally understood to be by volume, and it must be remembered:

1. That the volume of cement varies from 0.78 cu. ft. packed to 1 cu. ft. loose.

2. That, in practice, sand is never dried to constant volume; that its volume increases with addition of moisture; and that the volume of fine sand increases more rapidly with moisture than does coarse sand.

3. That, if an aggregate be of uniform size and rounded particles, it is difficult in practice to secure more than 56% of solids; while, if the aggregate be correctly graded, the porosity may be decreased indefinitely.

It is therefore evident that all specifications cited are defective, inasmuch as proportions are not specified by weight.

Again, given proportions may be ideal in one locality and totally wrong when applied to the local materials of another section. This fact will be appreciated by every cement-worker of wide experience, and the author has found it thoroughly exemplified in his visits to plants throughout the country. It is absolutely necessary that the required proportions to secure greatest strength, durability, density, and impermeability with a minimum quantity of cement be determined by expert tests upon local materials. The cost of such tests is infinitesimal in comparison to the saving in manufacturing cost and the marked increase in quality.

The amount of water should be clearly specified. It is folly to suppose that block-makers will always take the trouble—for under many methods it is trouble—to use the proportion of water necessary to secure the full strength of the cement. Either a certain percentage of water should be stated, or recourse should be had to the ordinary engineering specifications governing the three degrees of moisture in concrete. Normal consistency, like correct proportioning of the aggregate, is a matter for expert determination based on local conditions.

It is insufficient to say that blocks be three weeks or thirty days old. They must be CURED, and curing means more than age. It covers the most important period in block-manufacture; and it is essential that blocks receive, during this time, such scientific treatment as will lift the concrete-block industry to a higher plane.

The maximum percentage of hollow space is arbitrarily fixed at a figure which is unjust to an honest and intelligent manufacturer. This percentage should be in the nature of a sliding-scale based on compressive and transverse tests. There are many manufacturers marketing blocks which, with 50% or 55% of air-space in the walls, afford greater safety than blocks passing the requirements of the Philadelphia ordinance would afford with 25% of hollow space. The best authorities are agreed that properly made concrete will at four weeks show over 2,000 lbs. resistance to compression, and over 3,000 lbs. at one year. As a matter of fact, blocks 28 days old have tested 2,600 lbs. It is manifestly unfair to restrict such blocks to the same percentage of hollow space as blocks having an average crushing strength of 1,000 lbs. per square inch.

Relative to widths of walls, the standard specification, "equal in their combined width to the thicknesses required for brick walls," is manifestly unjust. The most eminent American authority on concrete architecture has rendered an opinion that a 10″ wall of properly made and properly bonded concrete blocks, laid in cement-mortar, possesses ample strength for three-story construction, and a 15″ wall for six stories. There is no doubt about an 8″ wall of good concrete blocks being strong enough for two-story construction, if the wall be laid in such manner that lateral stress is resisted by an efficient bond. The widths given in the author's paper published in the *Engineering News* of October 5, 1905, are 8″ for one story, 10″ for two stories, 12″ and 10″ for three stories, and 15″, 12″ and 10″ for four stories. These may be regarded as conservative.

CHAPTER XXVI.

MANUFACTURE OF ACCESSORIES.

The manufacture of sills, lintels, columns, caps, and other portions of buildings which may not be accurately termed building-blocks constitutes an important item in the work of every block-maker, not only because of their necessity in construction, but because of the relatively large profit obtainable by reason of the fact that they come into direct competition with the finest cut stone. It is not usual for the standard-block machines to make provision for this class of work, and recourse must be had to accessory equipment or local devices for manufacturing these members.

Fig. 43 shows one of the later and more practical sill-molds. The method of manufacture is similar to that employed in operating the building-block mold shown in Fig. 16, inasmuch as the mold is moved without disturbing the newly made sill. In the illustration the sides and ends are each $1\frac{1}{2}''$ from the sill, and the mold is ready to be lifted away, leaving the sill to cure on the board on which it was manufactured.

In many block factories it is preferred to make the molds for this class of work, using therefor lumber surfaced on one side and carefully sandpapered and shellacked; thus not only rendering the wood waterproof and preventing warping, but also overcoming the impression of the grain in the wood upon the molded sill. If this course be adopted, the sides should

have cleats to engage the ends, and a clamp should hold the sides in place at either end. A bottom-board of dimensions some-

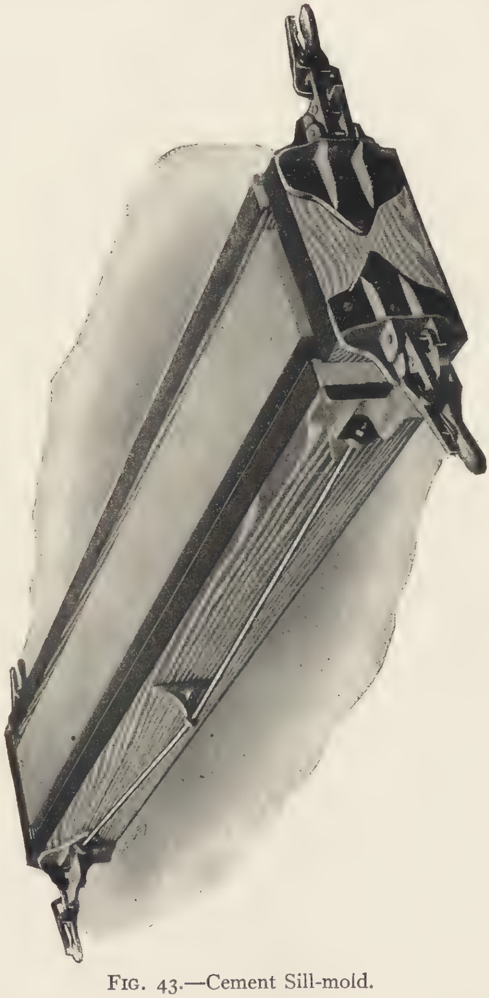

FIG. 43.—Cement Sill-mold.

what greater than those of the sill should be used. The face-matter should be put on the bottom and sides, and backed with coarse concrete as wet as can be tamped. When the sides are

unclamped and removed, the molded sill is left on the bottom-board, face down, until hard enough to permit of handling, and this time will, owing to the size and weight of the member and the fact of its being without hollow space, be much longer than required for an ordinary building-block. It will be noted that this method of molding the face is decidedly more favorable to sound and durable work than the customary manner of molding the sill face-up and troweling the surface, as the latter practice draws neat cement to the surface and results in hair- or map-cracks. These home-made molds may be varied by the insertion of thin wedge-shape strips before depositing the face-matter, to give any required bevel to the sill.

In molds of similar construction, by making one end-piece longer than the opposite end-piece, any desired radius may be obtained for arch-blocks and keystones. In making members requiring a molded effect, the insertion of any pattern of stock-molding, in the same manner suggested for the wedge-shape strips in the case of sills, will produce handsome results.

The more ornamental members, such as columns, caps, balusters, and the like, may be cast in sand or plaster, in the manner already described in the chapter on Ornamentation, although, if any considerable number are required, it will prove more economical to purchase iron molds for the purpose. These molds are comparatively easy of operation, and, while constructed on lines preserving the beauty of the original pattern, eliminate any undercutting in order to secure perfect release.

Figs. 44 and 45 show a few of the designs for which iron molds are obtainable. It is especially desirable that the one who is entering upon the manufacture of concrete blocks be equipped with molds for making some of the more attractive pieces, as the ability to show work of this class will disclose to builders the adaptability of concrete blocks for ornate construc-

Cap.

Column. Ball and Base. Balusters.

FIG. 44.—Ornamental Accessories.

tion; and the relatively low cost of this work in comparison with the same patterns in cut stone will secure ready consideration from the public. It will be found that the maintenance of a

FIG. 45.—Porch Column and Balustrade.

good exhibit of this class of work will have the twofold effect of directing the attention of prospective builders to the possibilities of concrete-block construction, and of selling considerable numbers of these special pieces for use in buildings constructed of ordinary building materials.

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